

Lawrence Berkeley National Laboratory

Recent Work

Title

A NEW METHOD FOR ION CHARGE STATE ANALYSIS

Permalink

<https://escholarship.org/uc/item/6fb977kg>

Authors

Brown, I.G.

Kelly, J.C.

Publication Date

1987-06-01



Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

Accelerator & Fusion Research Division

RECEIVED
LAWRENCE
BERKELEY LABORATORY

AUG 21 1987

LIBRARY AND
DOCUMENTS SECTION

Submitted to Applied Physics Letters

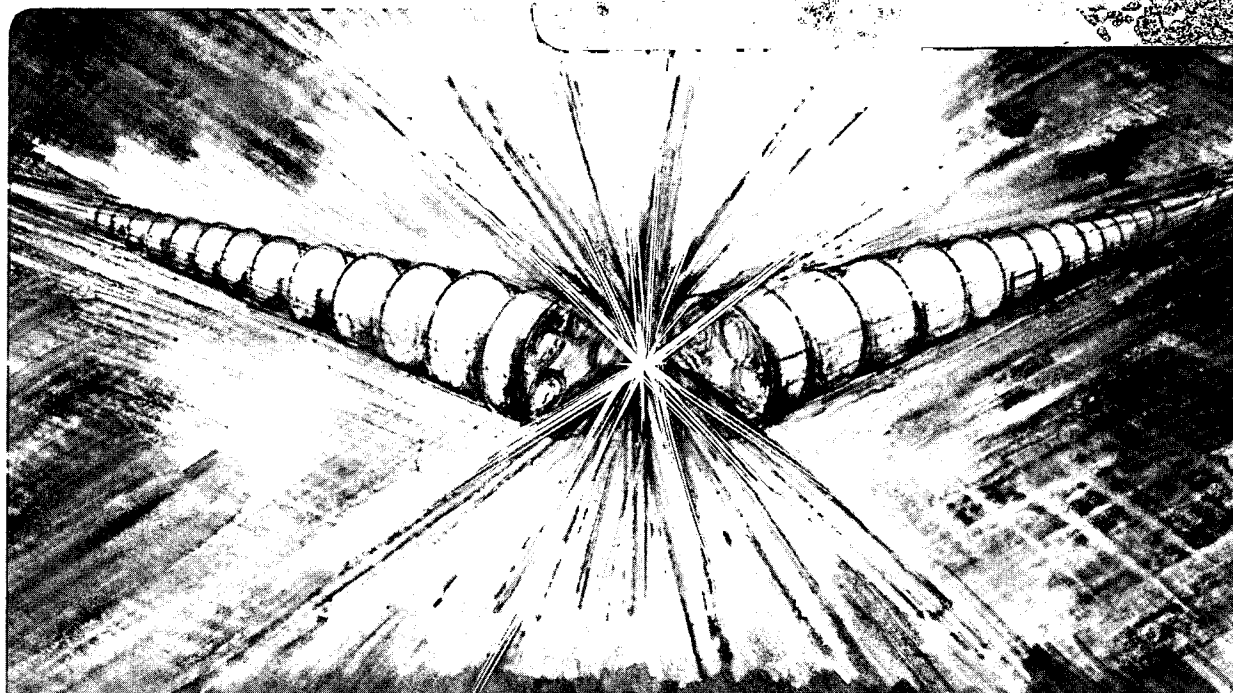
A NEW METHOD FOR ION CHARGE STATE ANALYSIS

I.G. Brown and J.C. Kelly

June 1987

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.*



LBL-23624
e.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

A NEW METHOD FOR ION CHARGE STATE ANALYSIS*

I. G. Brown^a and J. C. Kelly^b

^aLawrence Berkeley Laboratory
University of California
Berkeley, CA 94720 USA

and

^bSchool of Physics
University of New South Wales
Kensington, NSW 2033 Australia

June 1987

ABSTRACT

We present results showing charge state separation of an ion beam in a purely cylindrical geometry, using the azimuthal magnetic field of a straight conductor. This geometry, which we refer to as a current coaxial lens ("ICOL"), has advantages for the analysis of intense ion beams where it is important to minimize space charge blow-up of the beam due to loss of space charge neutralization.

* This work was supported in part by the US DOE under Contract No. DE-AC03-76SF00098.

It is usual for the ion beam produced by an ion source to be mass and/or charge state separated by transporting the beam through a transverse sector magnet [1]. For a beam extracted from the source through a fixed accelerating voltage, ions are deflected by the field through an angle which is proportional to $(Q/A)^{1/2}$, the square root of the charge-to-mass ratio of the ion species. The magnetic field thus provides a Q/A analysis, and if the beam optics is adequate, the various Q/A components can be selected out individually and transported downstream for further acceleration or for the application for which the beam is destined.

It has been conventional for the analysis magnetic field to be the homogeneous, transverse field established by a dipole magnet with two plane, parallel pole pieces, perhaps with minor field shaping to improve the beam optics. This kind of magnetic configuration has been well studied over many years, and has provided service in a wide variety of applications.

A new magnetic analysis configuration has been proposed by one of us [2,3], in which the magnetic field is created by the current flow through a straight conductor located on-axis with respect to the ion beam propagation direction. This magnetic geometry was called an ICOL, as an acronym for current coaxial lens. The magnetic field of an ICOL is purely azimuthal about the wire, and the beam Q/A components can be steered towards the axis (converging) or away from the axis (diverging) according to whether the wire current is parallel or antiparallel to the beam current.

We have conducted a simple experimental test of the ICOL concept by making use of the intense ion beam produced by the MEVVA (Metal Vapor Vacuum Arc) ion source that has been developed at Lawrence Berkeley Laboratory. We used an aluminum ion beam, containing charge state species Al^+ , Al^{2+} , and Al^{3+} . With the ICOL on, these components were separated such that the residual beam at the detector was almost entirely Al^+ alone.

Ions in the annular beam moving with velocity v parallel to the ICOL axis and at a distance r from it experience a force in the radial direction due to the azimuthal magnetic field $B = \mu I / 2\pi r$ produced by the current I in the ICOL rod. The radial force on the ions is $F = eQ(v \times B)$, so that higher charge state ions are deflected more strongly towards the axis than those of lower charge state. The system acts as a lens with a specific focal point on the axis which is different for each charge state. Charge state separation can thus be achieved by the provision of suitable apertures at the appropriate focus.

In the present case we have adopted the simpler procedure of using a long flight path and placing the Faraday cup near the focal region of the singly charged ions. This does not completely remove the higher charge states, but it would be straightforward to do so by the provision of suitably placed stops.

The experiment was performed by measuring the deflection of a short beam pulse due to the current through the ICOL, using an aluminum ion beam produced by a metal vapor vacuum arc ion source. A schematic of the experimental configuration is shown in Figure 1.

The MEVVA ion source has been fully described elsewhere [4-6]. This source produces pulsed high current beams of metal ions. In the present application, a beam of some tens of milliamperes of aluminum was extracted from the source at a voltage of 15 kV, with a pulse width of 250 microseconds and a repetition rate of about 1 pps. About 80 cm downstream from the ion source extractor an annular, electrostatic ion beam gate was located, consisting of 5 concentric pairs of circular deflection plates coaxially surrounding a central stop (which also serves as a beam current monitor) of radius 1.5 cm. In normal operation, a short pulse, about 0.2 microseconds long and typically 1 to 3 kV in amplitude, is applied to the gating plates so as to produce a short sample of the beam pulse, selected from near the middle of the main 250 microsecond long beam pulse, that is drifted a further 1.95 m downstream to a detector. In this way a time-of-flight charge state analysis system is formed. This system has been described in full elsewhere [7]. For the measurements presented here, only one pair of annular gating plates was used. Thus the beam that was seen by the detector further downstream was a

0.2 microsecond pulse gated through an annular region of mean radius 3.3 cm and annular thickness 1 cm. The detector was a well-shielded Faraday cup with magnetic suppression of secondary electrons provided by a transverse magnetic field. The ICOL element was a straight length of conductor extending on-axis for a distance of 63 cm downstream from the center of the annular gate array. Current for the ICOL was provided by a LC-pulse line of length 150 microseconds and characteristic impedance $Z_0 = 0.75$ Ohms; the line could be charged up to many kilovolts, and was discharged into a matched resistive load of 0.75 Ohms through the ICOL central conductor using a type 7703 ignitron.

With no current flowing in the ICOL conductor, $I_L = 0$, the downstream Faraday cup detected a signal that is typical of the time-of-flight charge state spectra that we routinely obtain from the MEVVA ion source. This signal is shown in the upper trace of Figure 2. Here the short gate pulse can be seen on the far left of the oscillogram, followed by the ion peaks corresponding to aluminum charge states $Q = 3, 2,$ and 1 ; sweep speed is 1 microsecond/cm and the vertical scale is 20 microamperes/cm. Thus the charge state spectrum measured at the detector is $Al^+ : Al^{2+} : Al^{3+}$ in proportion 43%:50%:7%. With ICOL current switched on and in the direction antiparallel to the ion beam flow, the current magnitude was adjusted so that the detector signal was as shown in the lower trace of Figure 2; for this case $I_L = 1.5$ kA, corresponding to an azimuthal magnetic field $B = 300/r$ Gauss (r in cm). The charge state spectrum has now been depleted of the Al^{2+} and Al^{3+} , and the spectral mix is now $Al^+ : Al^{2+}$ in the ratio 90%:10%. (The detector sensitivity was 5 microamperes/cm).

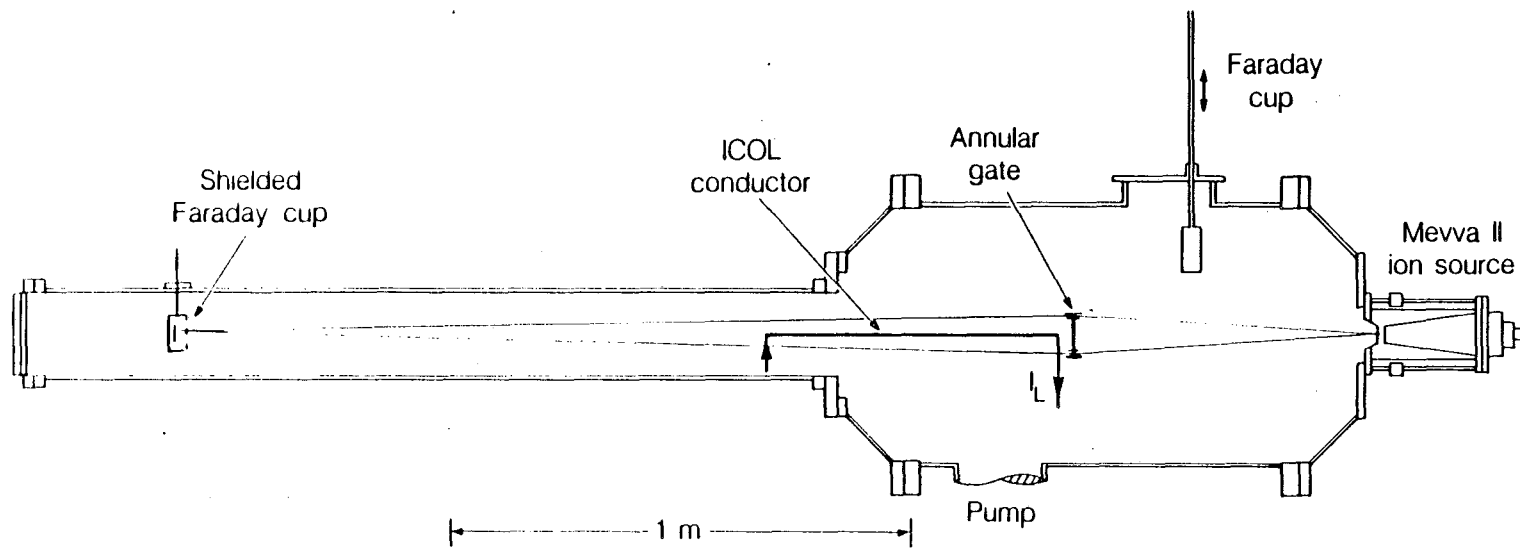
Although in this preliminary test of the ICOL concept the resolution of the separation is poor, the geometry was far from optimum. None-the-less it is clear that a charge state separation can be effected. Because of the cylindrical symmetry of both the magnetic and beam geometries, this magnetic analysis system has advantages over the more conventional dipole magnetic analysis system. We plan to test the ICOL separation system further, using a higher current density ion beam (around 100 ma total beam current) and improved ICOL optics.

ACKNOWLEDGEMENTS

We are indebted to Bob MacGill and Bob Wright for the design and fabrication of the ion source and mechanical facilities, and to Jim Galvin for the design and fabrication of the electrical systems.

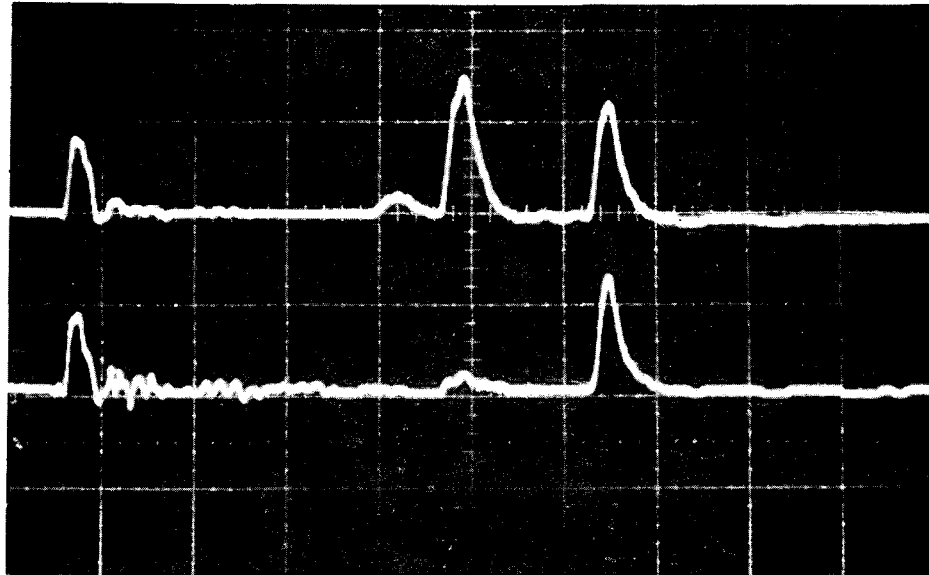
REFERENCES

1. P. D. Townsend, J. C. Kelly and N. E. W. Hartley, Ion Implantation, Sputtering and Their Applications, (Academic Press, New York, 1976), 166-169.
2. G. W. Kentwell and J. C. Kelly, Nucl. Instrum. Methods 205, 1 (1983).
3. J. C. Kelly, IEEE Trans. Nucl. Sci. NS-30, 1476 (1983).
4. I. G. Brown, J. E. Galvin and R. A. MagGill, Appl. Phys. Lett. 47, 358 (1985).
5. I. G. Brown, J. E. Galvin, B. F. Gavin and R. A. MacGill, Rev. Sci. Instrum. 57, 1069 (1986).
6. I. G. Brown, J. E. Galvin, R. A. MacGill and R. T. Wright, 1987 Particle Accelerator Conference, Washington, DC, March 16-19, 1987.
7. I. G. Brown, J. E. Galvin, R. A. MacGill and R. T. Wright, to be published in Rev. Sci. Instrum.



XBL 875-9663

Fig. 1. Simplified schematic of the experimental configuration.



XBB 875-4016

|
 Gate
 Pulse

Q : 3 2 1
 └──────────┘
 Aluminum

Fig. 2. Oscillogram of the ion beam current signal measured by the Faraday cup at the end of the time-of-flight chamber, for the case of zero current in the ICOL (upper trace), and for the case when $I_L = 1.5$ kA (lower trace). The two traces were taken consecutively. Sweep speed is 1 microsecond/cm.

*LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720*