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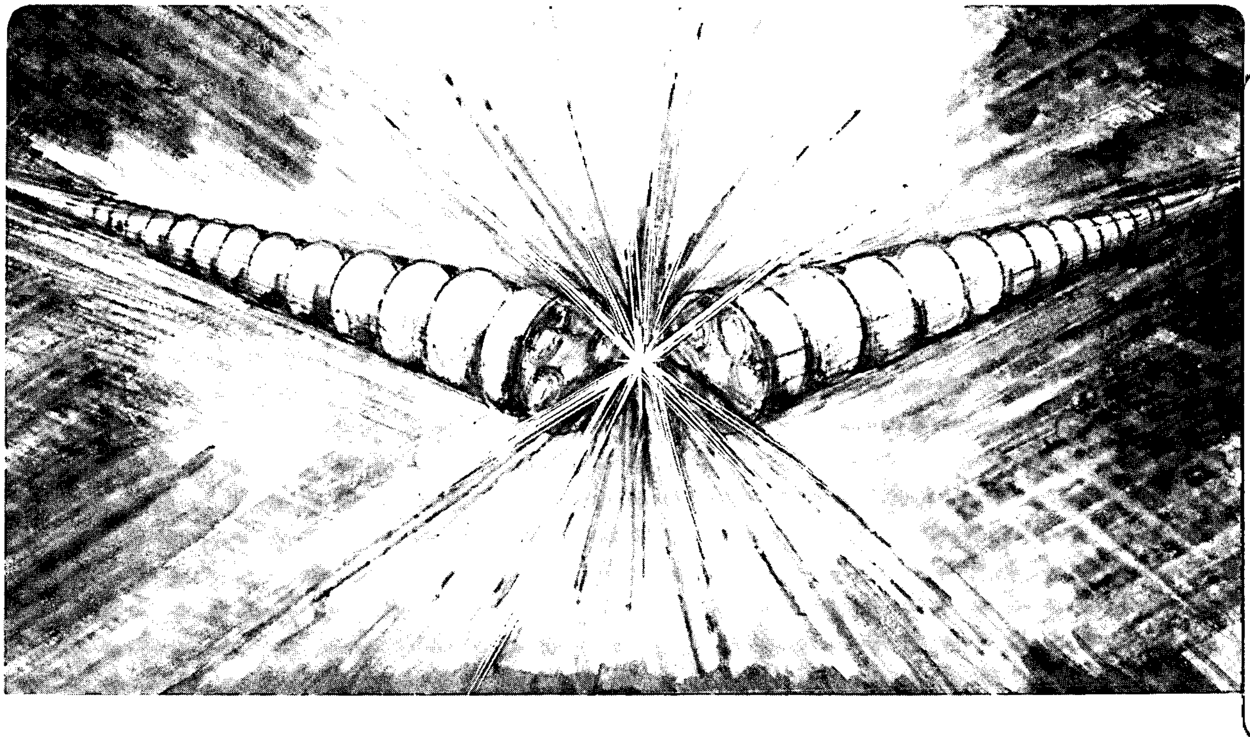

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Abstract

The Mevva (metal vapor vacuum arc) ion source provides high current beams of multiply-charged metal ions suitable for use in heavy ion synchrotrons as well as for metallurgical ion implantation. Pulsed beam currents of up to several amperes can be produced at ion energies of up to several hundred keV. Operation has been demonstrated for 48 metallic ion species: Li, C, Mg, Al, Si, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ge, Sr, Y, Zr, Nb, Mo, Pd, Ag, Cd, In, Sn, Ba, La, Ce, Pr, Nd, Sm, Gd, Dy, Ho, Er, Yb, Hf, Ta, W, Ir, Pt, Au, Pb, Bi, Th and U. When the source is operated optimally the rms fractional beam noise can be as low as 7% of the mean beam current; and when properly triggered the source operates reliably and reproducibly for many tens of thousands of pulses without failure. In this paper we review the source performance referred specifically to its use for synchrotron injection.

I. INTRODUCTION

Beam transport at the low energy injection end of a heavy ion synchrotron is a concern which becomes particularly important for high current beams because of the increasingly important role of space charge forces within the beam [1]. When the beam is transported through focusing or mass selection elements in which there are transverse magnetic field components, the maintenance of good space charge neutralization may be at risk if the beam suffers from too great a level of high frequency fluctuation in beam current. Another concern has to do with possible accelerator rf regulation problems that might arise due to fast changes in beam loading during the pulse. Beam noise is also a detriment to carrying out a wide range of experiments, quite apart from the concern of beam transport. Reproducibility of the beam pulse shape is important to the accelerator user and has bearing on the kinds of experimental techniques necessary to collect data. The operational lifetime of the ion source between scheduled maintenance periods and the downtime needed to change ion species are important to the accelerator operations and to the experimenter. The Mevva ion source is a powerful method for the production of pulsed, high current beams of metal ions. Here we summarize a range of observations that we have made about its beam noise, pulse shape reproducibility, triggering reliability, lifetime and charge state distribution.

II. EXPERIMENTAL BACKGROUND

The Mevva ion source has been described in detail elsewhere [2-6]. The experiments reported here were carried out both at LBL and GSI. At LBL the Mevva IV ion source embodiment was used; this is a multi-cathode source incorporating 16 separate cathodes in which the operational cathode can be changed by rotation of an external control knob. The source was mounted on a test stand which incorporates magnetically-suppressed Faraday cups for measurement of beam current and a time-of-flight diagnostic for measurement of the ion charge state distribution [7]. Beam extraction voltage was up to 100 kV and the total ion beam current was up to 570 mA. At GSI we used a source configuration in which the Mevva cathode stem was attached to the anode chamber of a CORDIS [8,9] ion source. Beam extraction voltage was up to 35 kV and the beam current measured 50 cm downstream was up to 40 mA. Experiments have been carried out using both an ion source test stand facility, and the injector terminal of the UNILAC heavy ion linear accelerator [10].

III. RESULTS

A. *Beam Noise*

The beam current fluctuation level varies according to the arc current at which the source is operated. There is an optimum operating point at which the rms fluctuation level reaches a minimum, typically about 7%. This operating point corresponds to the perveance match condition, at which the plasma density (which varies with arc current) is optimally matched to the extraction optics [11]. This optimum occurs for an arc current of about 100 A for the ion source used, and is only weakly dependent on metal species employed. Figure 1 shows a typical beam pulse for Ti at the optimum current level. Figure 2 shows the variation of beam noise as a function of arc current for a titanium beam. The GSI experiments found no difference in beam noise whether or not magnets were installed in the CORDIS multipole structure [12].

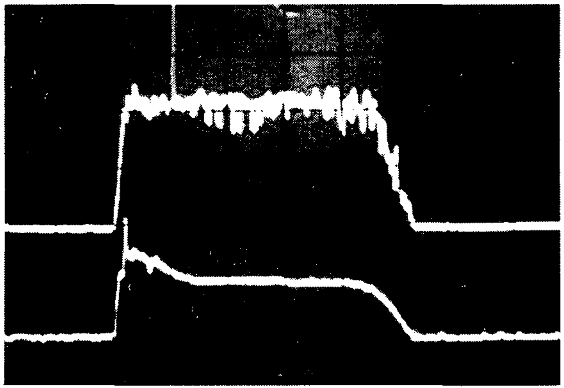

Fig. 1 Beam current pulse at perveance match. Upper trace: I_{beam}, 100 mA/cm; Lower trace: I_{arc}, 100 A/cm. Sweep speed is 50 µs/cm. Titanium beam. (XBB 890-9887)

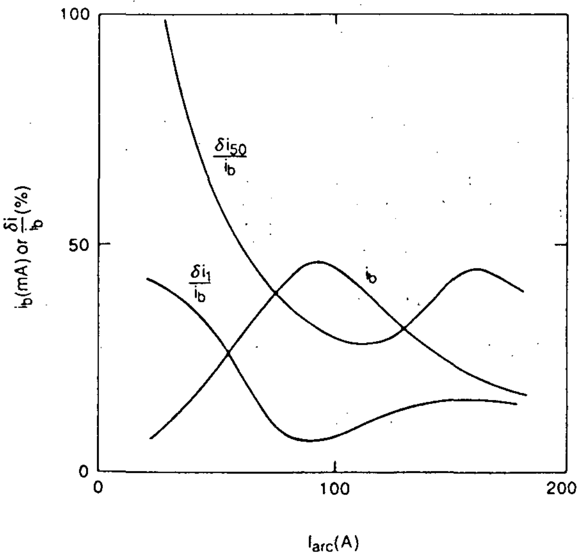

Fig. 2 Beam current i_b, fractional rms noise measured on a single-shot basis, $\delta i_1/i_b$, and the fractional rms noise measured for a sequence of 50 consecutive shots, $\delta i_{50}/i_b$, as a function of arc current. Titanium beam. Current measured 75 cm downstream from ion source by a 5-cm diameter Faraday cup. (XBL 8911-7325)

B. Shot-to-Shot Reproducibility

Variation in pulse shape from one pulse to the next is another performance characteristic that is important. Typical Mevva performance in this respect is shown in Figure 3. Here the oscilloscope was in "envelope mode" and thus recorded the envelope of pulse shape extrema for a succession of 50 beam pulses. The pulse amplitude varies from one pulse to the next by the extent indicated. Note that there were no missing pulses.

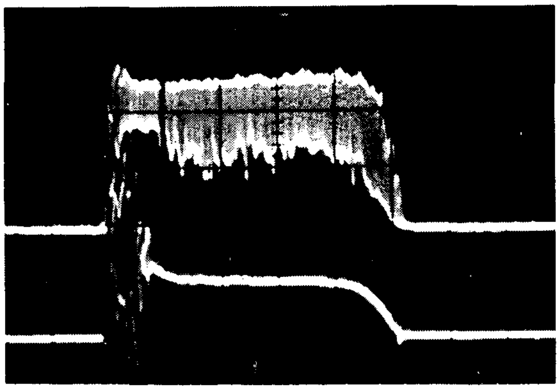

Fig. 3 Shot-to-shot variation in beam current at perveance match. Upper trace: I_{beam}, 100 mA/cm, this is the trace obtained when the oscilloscope is operated in envelope mode for 50 consecutive shots. Lower trace: I_{arc}, 100 A/cm. Sweep speed is 50 µs/cm. Titanium beam. (XBB 890-9887)

C. Triggering Reliability

It is important that the source trigger reliably for a large number of pulses before it must be removed for maintenance. The triggering failure rate should be small. We have found that when the trigger pulse is electrically adequate (peak voltage and total energy are the important parameters) and the trigger itself (annular alumina insulator) in good shape, then the triggering reliability can be excellent. As examples, the following triggering statistics were recorded for recent runs:

Cathode	Total pulses	Misfires
Pt	10,000	4 per 1000
Pd	10,000	0 per 1000
Ti	10,000	1 per 1000
Ti	100,000	10 per 1000
Ti	200,000	6 per 1000

Here "misfires" means the fraction of missing pulses (failure to produce a beam pulse when trigger pulse is applied), and "total pulses" means the number of pulses accumulated prior to making the misfires measurement. Some cathode materials (e.g., Mo) are difficult to make trigger reliably at arc current less than several hundred amperes.

D. *Lifetime*

The time for which the source can run between necessary maintenance periods is determined by the need for cathode replacement. Under typical operating conditions we obtain up to several hundred thousand pulses before the cathode is eroded away enough to require change. For the multi-cathode source embodiments (Mevva IV has 16 cathodes and Mevva V has 18) one can simply switch to another cathode at will, and in this way the total number of shots can be extended up to several million before needing to replace all the cathodes in the cathode assembly. At a pulse rate that might suit synchrotron application, say 4 pulses per second, the source can thus be run steadily 24 hours per day for a duration of order a week between changes. Cathode assemblies can be changed in an up-to-air time of less than a minute.

E. *Charge State Distribution*

The ions generated are in general multiply-stripped with a mean charge state of from 1 to 3, depending on the particular metal species, and the charge state distribution can have components from Q = 1+ to 6+. This means that the ion energy is greater than the extraction voltage by a factor equal to the charge state; for 100 kV extraction voltage the beam can thus be of mean energy up to 300 keV and can have components with energy up to 600 keV. Lower Z and lower boiling point metals tend to have lower mean charge state. An empirical expression that we have found to provide a reasonable predictor for the mean charge state (referred to the distribution in particle current) is

$$\overline{Q}_p = 0.38(T_{BP} / 1000 + 1)$$

where T_{BP} is the boiling point of the metal in °C. We have studied the charge state distributions in detail and the results have been reported in the literature [13-15].

IV. CONCLUSION

The Mevva ion source provides a means for the production of high current beams of metal ions that can be useful for accelerator injection, particularly for heavy ion synchrotrons. When the source is operated appropriately ("tuned" correctly) and triggered properly, characteristics such as beam noise, shot-to-shot pulse reproducibility, triggering reliability and lifetime can be excellent. The multiply-charged ions produced offer an advantage in beam energy for given extraction voltage.

ACKNOWLEDGEMENTS

This work was undertaken as part of an ongoing collaboration between the Lawrence Berkeley Laboratory and the Gesellschaft für Schwerionenforschung. That part of the work that was carried out at LBL was supported in part by the U.S. Army Research Office under Contract No. ARO 116-89, the Office of Naval Research under Contract No. 88-F-0093, and the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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