MEVVA Ion Source for Heavy Ion Synchrotron Injection

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Abstract

High current beams of metal ions are produced efficiently by a metal vapor vacuum arc ion source (MEVVA) and multiply charged ions can be extracted from this source. MEVVA ion sources are best suited for low duty cycle operation as required by heavy ion synchrotrons. With typical parameters (1 Hz and 250 μs pulses) the lifetime of one cathode is about one day and with up to 18 cathodes in a multicathode source three weeks operation with one source will be possible. At GSI a multicathode MEVVA ion source has been constructed and investigated. Especially pulse reproducibility and beam fluctuations have been studied. Test bench and Unilac injector results will be discussed.

Introduction

Metal vapor vacuum arcs occur between cold electrodes in vacuum. After ignition by a high voltage spark the vacuum arc plasma is maintained between cathode spots and the anode. From the cathode spots material is vaporized and feeds the discharge. The ionization behaviour in the region of the cathode spots mainly defines the arc plasma parameters.

Vacuum arcs have been intensively studied by many people since the twenties with focus on high power switches and vacuum valves (Hg arcs). The production of metal ions in vacuum arcs has also received attention during the last twenty years. A list of publications is given in ref. [1].

The metal vapor vacuum arc (MEVVA) ion source described here was developed by I.G.Brown (LBL Berkeley) during the last decade [2]-[5]. MEVVA ion sources can deliver small emittance beams of metal ions for particle accelerators or large area beams for ion implantation. This paper concentrates on the application of the MEVVA ion source as injectors for heavy ion synchrotrons. The principel arrangement of the MEVVA electrodes and the electric circuitry is shown in fig. 1.

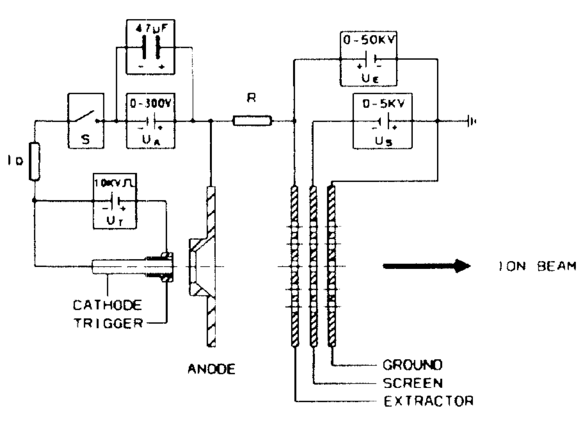

Figure 1. MEVVA ion source principle and circuitry.

MEVVA Ion Source Operation

The MEVVA arc is triggered by an electrode ring insulated from the cathode by an alumina pipe. The trigger is connected to the power supply which deliveres 10 kV pulses 10 μs long with a current of 10 A. The main arc is connected to a 300 V, 10 A power supply with a 47 μF buffer, a 1 Ω serial resistor and a transistor switch (fig. 1). The arc can be pulsed with .1 ms to 5 ms and up to 3% duty cycle depending on the cathode material. We run the source with 5 Hz and 500 μs at the test bench. For SIS we use 1 Hz and 200 μs conditions which give cathode lifetimes of more than a day or a lifetime of the complete ion source of more than 3 weeks. The ion current yield during the lifetime of a cathode is nearly constant and also varies little from one cathode to the next. The pulse to pulse reproducibility was in the range of $\pm$ 20% in these experiments, but smaller fluctuations have been reported [2], [8]. The ion current is modulated by higher frequencies especially some 10 kHz reaching about 30% . These fluctuations made beam optimization at the Unilac more difficult than with the Penning ion source commonly used.

Experimental Set Up

For the measurements we used either a MEVVA 2 ion source (GSI version) [6], [7] or a multicathode ion source of a design similar to MEVVA 4 [4]. Fig. 2 shows a sectional view through MEVVA 4 (GSI version). The source has 18 cathodes which are made either from the same material for long term operation or from different materials if a change in ion species is needed. The cathodes are mounted in a watercooled copper cathode block and can be moved in front of the anode by a telecommand motor. The arc plasma expands through a hole in the anode into an expansion area which is connected to the anode via a resistor. The expansion area ends in an extraction grid which can use an area of 5 cm in diameter for ion beam extraction. In these experiments we used an extraction area of 0.65 cm^2 only because of limitations in beam current imposed by the high voltage supply of our injector. The MEVVA ion source with the extraction system was tested at a 50 kV test bench and later mounted on the 300 kV platform of the Unilac (fig. 3).

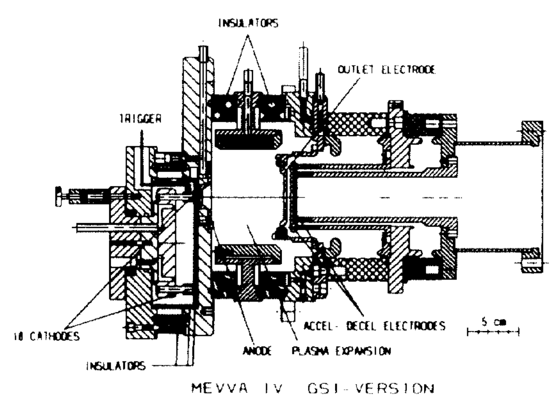

Figure 2. Sectional view of multicathode MEVVA ion source.

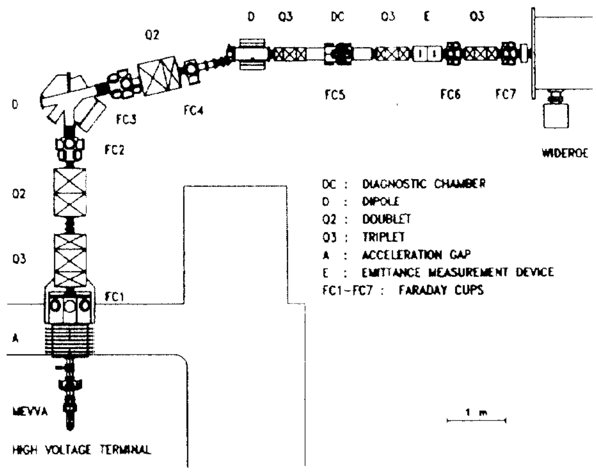

Figure 3. Unilac injector beam line.

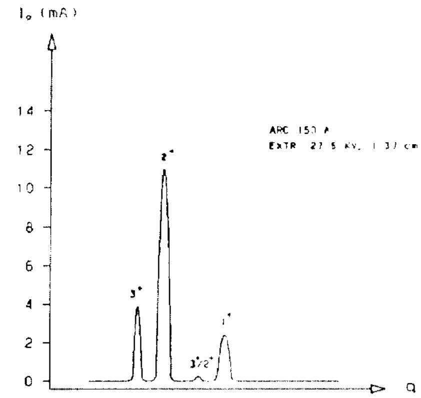

Figure 5. MEVVA charge spectrum for nickel.

Results at the Test Bench

We investigated total ion current and charge state distribution for some metals at the high current test bench described in [6], [7]. Charge state distributions for most metals have been measured before by time of flight methode [2]. We used a magnetic analyser to detect the different charge states.Spectra for titanium and nickel are shown in fig. 4 and 5 respectively. For these medium weight elements the main charge fraction is 2^+ with fair amounts of 3^+ ions. For the Unilac and SIS [7] we need Ti^{2+} or Ni^{3+}.

The total ion current increases linearly with increasing arc current within the range of operation of the ion source (fig. 6). The same behaviour was observed for the different charge states (fig. 7) but with varying slopes i.e. the charge state distribution varies slightly with arc current towards higher charged ions.

For the charge states requested by Unilac we measured 6 mA of Ti^{2+} and 2.5 mA of Ni^{3+}. The total extracted ion current was 30 mA in both cases and the transmission of the test bench about 35 %. The high frequency modulation of the MEVVA total ion current mainly in the kHz region is shown in fig. 8 for titanium beam.

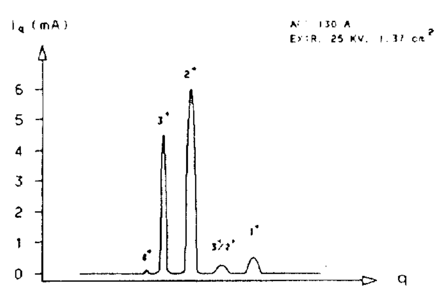

Figure 4. MEVVA charge spectrum for titanium.

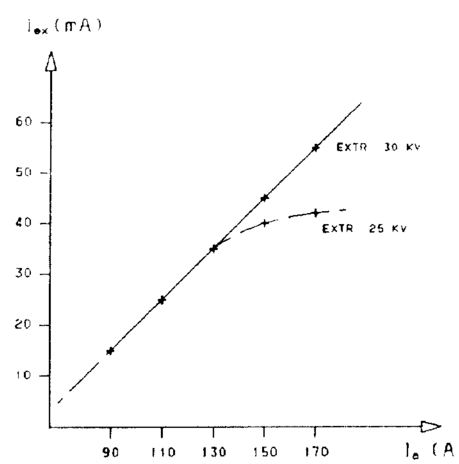

Figure 6. Total ion current as a function of the arc current.

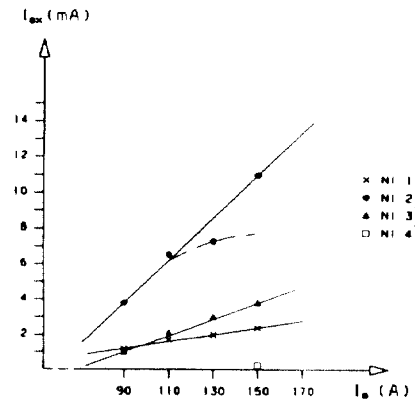

Figure 7. Ion current of nickel charge states depending on the arc current.

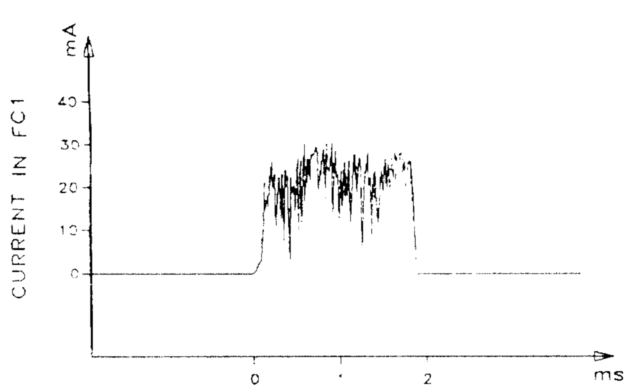

Figure 8. Modulation of total ion current.

Results at the Unilac Injector

After the investigation of the MEVVA ion source at the test bench we mounted the source without separation of charge states on the Unilac injector to get a Ni^{3+} beam for SIS. After preacceleration with 20 kV the ions were postaccelerated with 200 kV in a 120 mm gap with HV- and ground electrode diameters of 40 and 50 mm respectively. We measured 30 mA ion current after acceleration but in contrast to previous experiments with titanium [6] we found severe space charge problems this time and got a broad beam which filled the aperture of the following beam line. Nevertheless we measured up to 1.5 mA of $^{58}Ni^{3+}$ after the analysing magnet and 0.8 mA in front of the Wideroe accelerator which is roughly a factor 4 more than with the Penning source. Test runs to optimize the transport through the Unilac are going on.

Conclusions

The MEVVA ion source is a promising ion source for the heavy ion synchrotron SIS for light to medium weight metal ions. The life time of the MEVVA source is sufficient for routine operation at the accelerator, but beam transport and pulse to pulse reproducibility should be improved. Nevertheless, the ion current achieved for nickel in front of the Wideroe accelerator is already 4 times the current delivered from the Penning ion source. Further improvements of MEVVA ion source operation are planned for the near future and also tests with other metal elements for the GSI accelerators and ion implantation facilities.

References

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