Abstract. Cancer therapy synchrotrons profit from single turn injection in terms of size, costs and easy operation [1]. The MEditionally Dedicated EBIS (MEDEBIS), built in Frankfurt, will deliver short (~1.5 µs) and intense (~1.3 mA) pulses of highly charged light ions (C, N, O) to meet the requirements for therapy facilities. The MEDEBIS operates with an electron beam of 400 mA at 5 keV and a ratio of beam to drift tube of 1/20. Drift tube potentials up to 1.6 kV are switched in some 100 ns to deliver a 1.5 µs ion pulse at an axial field gradient of 6.5 kV/m. On extraction, all potentials applied to the drift tubes are set to a given primary potential to define the extraction gradient. During extraction the drift tubes are not held at constant voltage to avoid spreading out of the pulse due to the restoration of the full space charge depression at locations where ions have already been extracted. To locally distribute the action of the applied potentials the drift tubes are fully interpenetrating each other with tapered fingers. Combining these features result in a potential wall, which follows the extracted ion pulse and produces a compressed short ion pulse for single turn injection. In the future similar constructions could be considered for the RHIS EBIS device or proposed for LHC to provide the advantage with respect to lowest emittance and highest luminosity to the accelerators at BNL and CERN.

INTRODUCTION

Using pulsed mode operation and ion pulse extraction times down to some µs, EBIS devices deliver highest charge states of ions. Depending on the synchrotron’s diameter, the mass of the ions and the injection energy, a few µs is the time range needed for single turn injection matching the synchrotron’s cycling time. Hadron therapy will benefit from single turn injection as this is a step towards simplification [2]. In the case of hadron colliders there would be additionally a benefit in luminosity [3].

ION EXTRACTION ELECTRONICS

In EBIS devices the extraction of the ions will be usually performed by either lowering the potential of one confinement electrode or by applying higher potentials to all trap electrodes with a gradient in direction of extraction. As a result from the non neutralized electron beam upstream of the actual position of the already extracted ions, both extraction modes implicitly cause an unwanted spread in the time profile of the ion pulse. This leads to an increase of the extraction time.

An extraction scheme presented at the EBIS Symposium in November 2000 at BNL, USA [4] encounters this problem in preventing the potential drop with a time dependent variation of the potential applied to drift tubes one after the other in direction of the extraction. To apply the appropriate high voltages to the drift tubes
fast switching electronic circuits have been realized using silicon diffused power transistors. Using a BU508 DF results in minimum pulse rise times of < 150ns in the case of 1200V, which is the drift tubes potential wall value for the MEDEBIS trap [4].

**Figure 1:** Electronic setup for pulse shaping. Trigger times have to be chosen to raise the potential on each drift tube according to the ion pulse acceleration inside of the EBIS.

To apply the appropriate high voltage pulses for the accelerated potential wall all potentials, time constants and rise times need to be independently adjustable for any drift tube.

All high voltage pulses will be applied to the drift tubes in two stages: a.) providing the extraction gradient and b.) full raise to generate the moving potential wall. According to a total extraction time of the complete ion spill in the range of µs, time constants of a few 100 ns to build up the voltages are required.

**Figure 2:** The potential during extraction will be first raised to a.) which assigns an extraction gradient to the trap. After the ion spill has left the region of a designated drift tube, the corresponding potential will be raised in b.) to the level of the potential wall. Show in figure 2 are the 3 sequential potentials applied to the drift tubes. One channel out of the 4 possible channels of the oscilloscope is used to trigger the start of the fast pulses and is not displayed in the figure.
DRIFT TUBE MODIFICATIONS

Plain cylindrical electrodes provide a staircase shaped potential function, while drift tubes, which provide a steady and linear potential function need to be mutually interpenetrating cylinders.

**Figure 3:** The MedEBIS Setup consists out of 9 drift tubes forming a 0.24m trap around an electron beam of max. 5kV and 400mA. Each drift tube interpenetrates with its opponent to generate a smooth linear gradient along the axis of the ion trap. To shield and suppress unwanted rf-influences each drift tube is connected with the high voltage pulser using UHV compatible coaxial cable.

EXTRACTION ELECTRONICS

All extraction pulses are generated using a 2 stage high voltage pulse generation presented in figure 2. A Timer/Generator triggers the individual timings for each drift tube as well as the pulse repetition rate. An Analog/Digital converter allows to adjust the individual potentials for each drift tube using low voltage memory circuits, while an Optocoupler galvanically decouples the low voltage operating part from the high voltage.

**Figure 4:** Complete schematic diagram of the switchyard for the final application and pulse formation for the MEDEBIS extraction.

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