FIRST RESULTS FROM THE LEIR IONISATION PROFILE MONITORS

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Abstract

The role of the Low Energy Ion Ring, LEIR, is to transform long pulses of lead ions from the Linac 3 to short dense bunches for transfer to the LHC. This is accomplished by the accumulation of up to 4 Linac pulses by electron cooling. In order to non-destructively monitor the cooling performance and determine the accumulated beam characteristics, two prototype ionisation profile monitors have been built and were tested during the LEIR commissioning runs with O^{4+} and Pb^{54+} ions in 2006.

In this paper we present the results obtained with the prototype monitors, the problems encountered and describe the modifications made for the final design. The modified monitors have been installed on the LEIR machine and are waiting for the next ion run planned in August.

INTRODUCTION

The LHC program foresees lead-lead collisions in the spring of 2008 with luminosity up to 10^{27} $cm^{-2}s^{-1}$. The Low Energy Ion Ring (LEIR) has undergone a major upgrade [1] in order to prepare these dense bunches of lead ions by the transformation of ion beam pulses from the Linac 3 into short high-brightness bunches using multi-turn injection, cooling and accumulation.

Electron cooling [2] plays an essential role in producing the required beam brightness by rapidly cooling down the newly injected beam and then dragging it to the stack. The cooling performance can be measured by various diagnostics such as Schottky scans or scrapers [3] [4]. For the non-destructive measurement of the circulating beam emittance, ionisation profile monitors (IPM) are widely used. In such devices an electrostatic field accelerates the ionisation products from the beam-residual gas interaction towards a micro-channel plate (MCP). Either the electrons or the ions can be used for beam profile detection and when these particles reach the MCP, secondary electrons are produced, amplified and accelerated on to a readout device.

A major challenge for the new devices was their integration into the LEIR ultra high vacuum environment, requiring a bakeout of the apparatus at 300ºC, and where the choice of materials is critical in order to ensure that the average vacuum level in the ring (2 x 10^{-12} torr) is not perturbed by the operation of the monitors. Another constraint was the physical space allocated to the monitors, forcing us to make compromises with respect to the detector dimensions and also to pay careful attention to the readout.

DETECTOR DESIGN

The detectors (see Fig. 1) are essentially of the same design for the horizontal and the vertical profile measurements, differing only in their physical dimensions and the resolution of the readout. The two electrodes creating the electric field are made of 316LN stainless steel and are separated from each other by two 1 cm thick aluminium oxide (AL_2O_3) blocks. The top electrode has a rectangular area corresponding to the size (80 mm x 30 mm) of the MCP cut away in its centre.

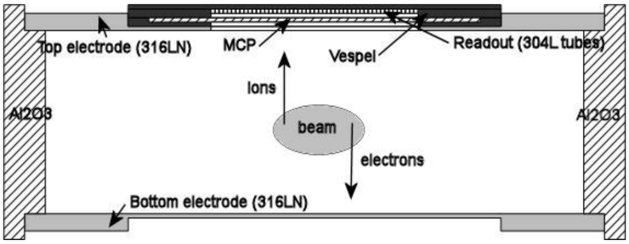

Figure 1: Drawing of the horizontal IPM.

The MCP is supported in a Vespel sandwich on top of which is placed the signal readout. The readout (see Fig. 2) consists of up to 80 AISI 304 stainless steel tubes of 0.8 mm diameter placed on a grooved Vespel plate. The total thickness of the MCP support and the readout is 4 mm. A thin kapton wire is pinched to the end of each tube and carries the charge deposited on the readout to UHV flange mounted sub-D connectors. The air-side connection to the readout electronics is made by a flat ribbon cable. In the horizontal plane, due to a limitation on the number of sub-D connectors that could be mounted on the vacuum flange, we were only able to use 50 tubes which were spaced by 1.5 mm. This ensured that the profile of the newly injected ion beam could be measured. The vertical measurement has 80 readout channels with a spacing of 1 mm. The charges collected by each readout channel are integrated by means of R-C electronics.

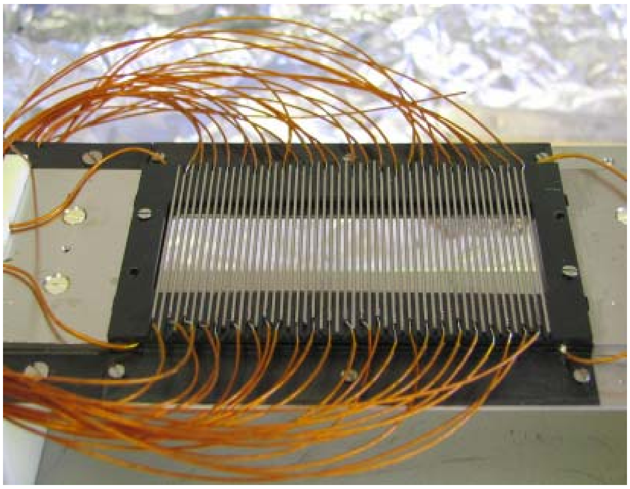

Figure 2: The horizontal readout.

CONTROL AND DATA ACQUISITION

The control and data acquisition of the IPMs is handled by the ADwinPro system. The ADwin hardware consists of a dedicated real-time processor, fast analogue and digital inputs and outputs and an ethernet link to the local area network. Low priority tasks perform the control of the 8 high voltage power supplies needed to polarise the electrodes and the MCPs. An externally triggered high priority application takes care of acquiring the 130 data channels with the necessary time resolution. Typically, horizontal and vertical profiles are acquired every 20 ms. An example of an acquisition cycle is shown in figure 3.

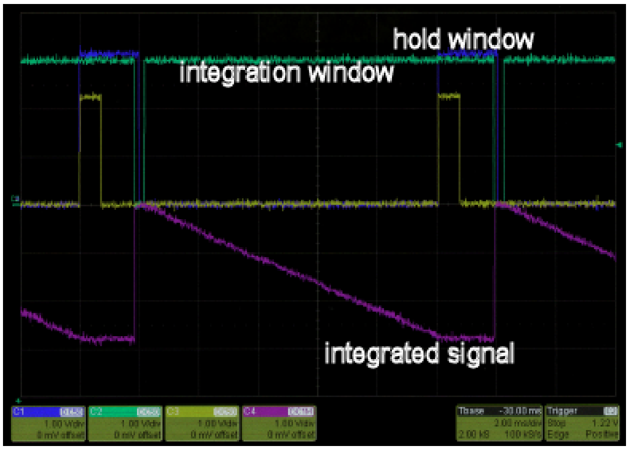

Figure 3: Acquisition cycle for the RC integrators.

The R-C integrator chips are controlled by two Agilent 33220A waveform generators providing the integration and hold windows. When the signal for the integration window (green trace) is high, the circuit starts the integration of all the channels. After the desired integration time has elapsed, a hold window (blue trace) is generated and the analogue to digital conversion of the signals is made via 14 bit ADC modules of the ADwin system. The total time needed to acquire all 130 channels of the horizontal and vertical monitors is 770 µs.

Profile Time [ms] 25.00

Plane Horizontal

USER NOMINAL

Vgun 0

Vgrid 0

Vcont 0

Figure 4: IPM acquisition application.

The acquired data is stored in the local memory of the ADwin system and can be transferred to any data analysis program on any computer on the local area network. In our case we used an application written in TestPoint running on a windows based PC. TestPoint is a tool for creating custom test, measurement, and data acquisition applications and includes features for controlling external hardware, creating user interfaces, processing and displaying data, creating report files, and exchanging information with other Windows programs. The interface panel for the TestPoint IPM application is shown in figure 4. The application provides the means to visualise the individual profiles and to store all the data to file for post analysis.

A more detailed analysis of the cooled beam profiles can be made using a dedicated data analysis package called FlexPro (see Fig. 5). Using this package we can display the data in a variety of ways enabling us to extract all the necessary information concerning the cooling/stacking process and the characteristics of the ion beam before its transfer to the next accelerator in the LHC ion injector chain.

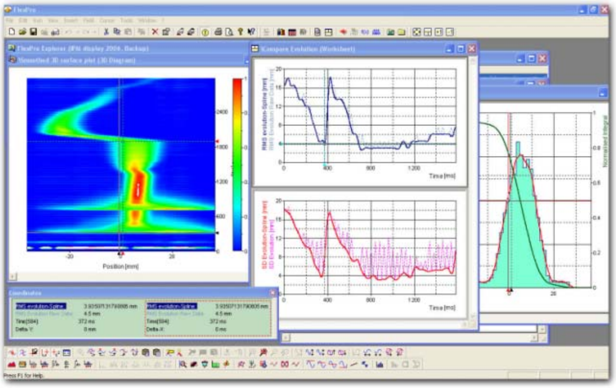

Figure 5: FlexPro data analysis interface.

RESULTS

Test with O^{4+} Ions

The first tests of the IPMs were made at the end of 2005 during the LEIR commissioning run with oxygen ions. Clear signals from the rest gas ionisation were seen but an error in the cabling of the readout made the reconstruction of the beam profile laborious. By the time this cabling error had been resolved, we started to experience high voltage problems in the vicinity of the MCP and readout. As a consequence many of the integrator inputs were damaged and we were obliged to modify the readout electronics boards with a diode protection for each input channel.

Profile measurements with Pb^{54+} Ions

Before the start of the lead ion run it was decided to open the vacuum sector where the IPMs are installed in order to try to understand the origins of the high voltage problems. Investigation of the vertical monitor showed traces of direct beam impact on the readout and the kapton wires and some damage of the MCP was observed on the horizontal monitor. Out of precaution, this MCP was exchanged and gold plated collimators were welded onto the vacuum chamber at the entrance to the vertical IPM in order to protect the monitor against any impact from the ion beam.

Unfortunately the situation did not improve during this run and we still experienced numerous high voltage breakdowns. It became clear that the plate resistance between the faces was slowly deteriorating because of these ongoing HT problems. This obliged us to decrease the voltage across the MCP, thus lowering the gain of the system. When the monitors were removed from the machine in December 2006 for modifications, the two MCPs were found to be damaged at many points.

Despite these problems we were still able to make many beam profile measurements which confirmed the excellent performance of the electron cooler. The evolution of the beam size (see Fig. 6) as seen by the IPMs gave invaluable information for the setting up and optimisation of the accumulation process. Detailed studies of the electron cooler (cooling times & lifetimes, equilibrium emittances etc.) were also possible with the individual profile acquisition time as short as 10 ms when the highest MCP gain was used.

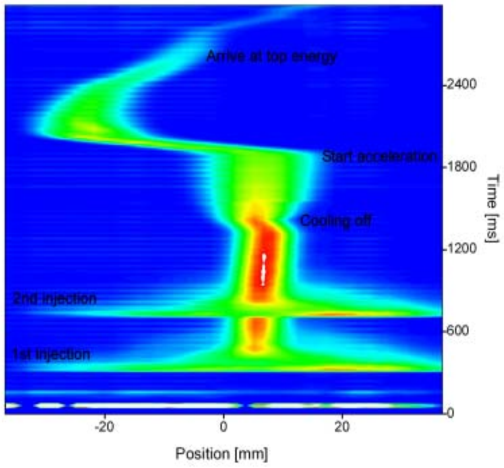

Figure 6: Evolution of the horizontal ion beam size during the whole LEIR cycle.

CONCLUSION AND OUTLOOK

The ionisation profile monitor has proved to be an invaluable tool for the commissioning of the low energy ion accumulator ring at CERN. Despite a problem with the high voltage insulation between the readout channels and the MCP, we were still able to make fast (<<20ms) acquisitions of the beam profiles needed for the fine tuning of the cooling/accumulation process. This was mainly due to the excellent signal level coming from the rest gas ionisation by the lead ions and collected on the readout.

From the experience gained with the prototype monitors we have made a number of modifications to the design in order to overcome the high voltage problems that we encountered during the LEIR commissioning. The main modifications are:

- The use of a softer grade Vespel such that degassing grooves can be etched onto the plates that hold the MCP and the readout. This should help to avoid a build up of molecules in the volume around the MCP which can lead to high voltage breakdown.
- The high voltage on the MCP faces is better distributed by using a thin beryllium-copper frame around the whole MCP (see Fig. 7). On the prototypes, the HT contact was made only along one edge.
- Separation of the HT and readout wires. The four HT wires are grouped together and pass below the electrode opposite to the readout. The connections to the top electrode and MCP are made as far away from the readout as possible (see Fig. 7).
- The ADwin control and acquisition system has been connected to the computer technical network and the software modified for remote operations from the CCC.

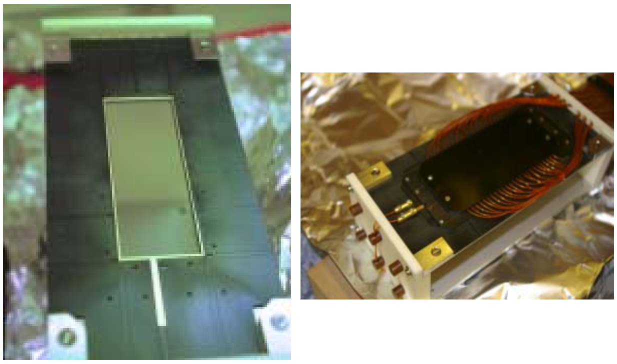

Figure 7: New Vespel plate design (left) with degassing grooves. The beryllium-copper frame used to evenly distribute the high voltage on the MCP face is also visible. On the right, the MCP high voltage connections

The new monitors were designed and built in the second half of 2006 and have been installed in the LEIR ring during the annual shutdown. Prior to the installation of the vertical monitor, a bakeout was made of this detector in its vacuum tank in the laboratory to check the quality of the vacuum when the MCP is polarised. The test showed that the vacuum quality is not at all affected by this monitor and no high voltage breakdowns were experienced, even with the MCP running at its maximum gain i.e. a voltage difference of 1.6 kV across the faces.

The commissioning of the definite detectors will take place during the next ion run planned to start in August this year.

REFERENCES

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