A MICRO-CHANNEL PLATE BASED GAS IONISATION PROFILE MONITOR WITH SHAPING FIELD ELECTRODES FOR THE ISIS H^- INJECTOR

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Abstract

Beam profile measurements along the ISIS H^- Injector line are achieved using destructive diagnostics such as moving wire scanners. To prevent damage to the wires, measurements are only made when the injector is operating on reduced power, for example during machine set up. This paper reports the development of a non destructive, Micro-Channel Plate (MCP) based gas ionisation profile monitor. The MCP assembly includes a segmented anode comprised of 32 elements or channels positioned along the 81mm active length of the MCP. Calibration of the monitor is achieved by rotating the MCP parallel to the beam direction, so all 32 channels detect the same magnitude of input (+ion) current which results from the beams interaction with the surrounding residual gas. A 15kV drift field is used to drive the +ions into the MCP. The drift field arrangement includes shaping field electrodes to improve the transverse field shape. Shaping field upgrades to improve the longitudinal field shape are discussed. Beam profiles obtained from a nearby scanning wire monitor are compared to profiles obtained from the new profile monitor.

INTRODUCTION

The ISIS H- Injector consists of an ion source, a 665keV Radio Frequency Quadrupole followed by a four tank drift tube linac which accelerates the H^- beam up to 70MeV. The pulsed H- beam (50Hz, 200µs pulse length) is then passed through a High Energy Drift Space (HEDS) before being injected into the 800MeV ISIS Synchrotron. Normally beam profile and position measurements in the HEDS are taken using wire scanning monitors. Because these monitors interact directly with the beam, there is a need to reduce the risk of damage to the wires and to minimise the beam loss they cause. For these reasons the wire monitors are only used when ISIS is running 1.6Hz beams, i.e. during machine setup.

To overcome these operational restrictions a Micro-Channel Plate (MCP) based gas ionisation Injector Profile Monitor (IPM) has been developed and installed in the HEDS. It is designed to measure the profile in the horizontal plane only, at a point of high horizontal dispersion. The monitor produces profiles by measuring the +ion current resulting from the interaction of the H^- beam with the surrounding residual gas. The MCP is mounted on a rotating arm to enable it to be positioned parallel to the beam for calibration purposes (see calibration section). A 15kV drift field is employed, together with field shaping electrodes, to ensure a uniform electric field gradient across the monitor, thereby minimising distortion of the profile due to the electric field.

THE DETECTOR

The IPM, shown in Figure 1, uses a Hamamatsu F2813-22MXC MCP assembly [1] which has an 81 x 31mm effective area. The MCP is positioned over a segmented anode assembly (comprising of 32 equal sized rectangular elements or channels) etched onto a ceramic substrate. The MCP is mounted inside a frame which is attached at the end of a rotating arm within the vacuum vessel. Rotational motion is transmitted through the vacuum boundary using a magnetically coupled rotary drive.

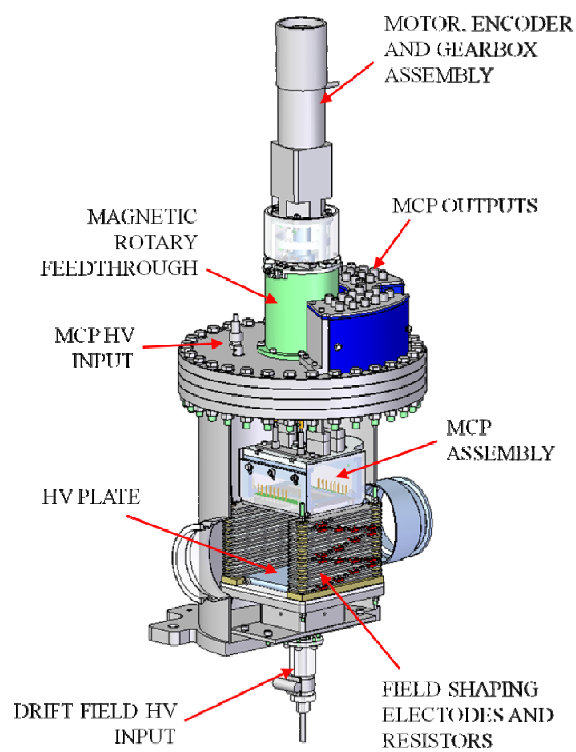

Figure 1: CAD drawing of the IPM assembly

Electrical connections from the static vacuum flange to the rotating MCP assembly have been made using Kapton coated copper wire which offers low out gassing combined with high radiation resistance properties [2]. The forces on the connections, caused by the rotational motion, have been minimised using custom made clamps.

Rotation of the MCP assembly is achieved using a radiation hard stepper motor, passing through a 70:1 gearbox to increase the precision of the rotational motion. A rear mounted radiation hard resolver provides positional feedback,

A micro-switch provides reference position data for the calibration and measurement locations. The number of steps to position the MCP at either of these positions was accurately measured from this switch. A move to this reference position is performed before each use of the IPM to ensure accurate rotational positioning of the MCP.

The 15kV drift field and field shaping electrode assembly are located in the base of the IPM vacuum vessel. The 2mm thick stainless steel shaping field electrodes are separated by 3mm PEEK insulators and electrically linked by a chain of resistors. The values of the resistors were determined using the CST EM Studio software [3]. The effects of these shaping electrodes can be seen in Figure 2.

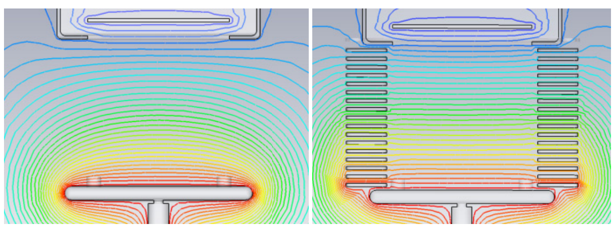

Figure 2: Simulations of transverse bias field at the centre of the IPM without (left) and with (right) the field shaping electrodes

CONTROL AND DATA ACQUISITION

The control and data acquisition systems for the IPM consist of front end and motion control electronics, two high voltage power supplies and a PXI (PC based DAQ system) running LabVIEW [4].

Power Supply Controls

The bias voltage for the MCP is supplied from one channel of a -2.5kV CAEN SY2527 power supply [5]. The power supply is controlled through the use of an OPC server across TCP/IP. A separate 15kV programmable power supply is used to supply the drift field, and is connected to the PXI via a purpose built interlock unit designed to provide both personnel and vacuum loss protection. Analogue signals are used to both control and monitor the output voltage of the power supply.

Motion Control

The motion control electronics consist of a stepper motor controller and a resolver decoder. Control of the motor controller is achieved using RS232 serial communications from the IPM program on a PXI. Feedback from the resolver decoder is fed directly into this motor controller to ensure accurate position is constantly maintained. The standard function of the program is automated, i.e. it moves between the calibration position and measurement position when required. There is the option of full manual control for testing purposes.

Data Acquisition

Each element of the MCP anode is connected to one of 32 pre-amplifiers. These amplifiers have an input impedance of 10 kΩ, a transimpedance gain of 2 MΩ and a bandwidth of 10 kHz. The output from the pre-amplifiers is captured by a set of four, 8 channel, 14 bit PXI-6133 digitizer cards.

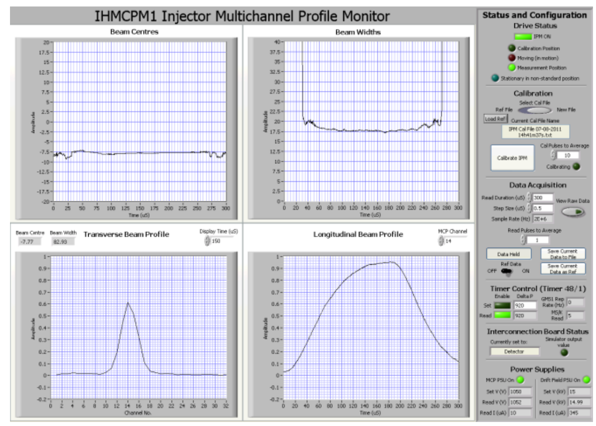

Figure 3: LabVIEW front panel of the IPM program

The LabVIEW user interface consists of four graphs (see Figure 3) which are user selectable; Beam Widths, Beam Centres, Transverse Profile, Longitudinal Profile. A 3D display of the profile data is also available. Transverse profiles are time selectable for any point in the injection cycle. A numerical display for the beam position and width data is included. Profile data can be either stored as a reference trace on screen or saved to text files for later use. Saved data consists of a current screen shot, the current calibration file, the raw and currently viewed data, the beam centres, beam widths and sample times.

CALIBRATION

Gain variation across the surface of an MCP can be as much as 20% or more [6]. The gain variation figure can increase further still as the MCP ages with use [7]. To remove this source of error, calibration of the monitor is required. Calibration is achieved by rotating the MCP so the 32 channels of the monitor lay along the beam path rather than transverse to the beam path as in normal use. This technique ensures all channels of the monitor receive the same magnitude of (+ion) input current.

Whilst in the calibration position, the acquired data from each channel of the MCP is averaged over ten injected beam pulses. This data is then divided by the median of all 32 channels values. This method produces an array of ‘calibration factors’, one value for each channel of the MCP. An example of the effect of gain variation before and after calibration can be seen in Figure 4. The dip in the blue trace is caused by aging of the MCP.

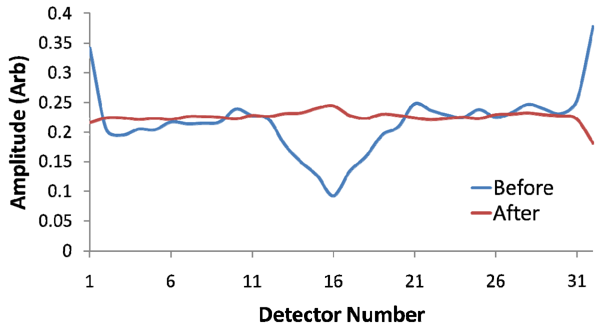

Figure 4: A comparison of IPM output before and after calibration of the MCP.

COMPARISON TO WIRE SCANNING PROFILE MONITOR

Profile measurements have been made with both the new MCP based monitor and an existing scanning wire profile monitor located approximately 1m downstream of the new monitor. Results show strong agreement between beam centre measurements and an expected difference between the profile widths for the IPM monitor and the wire scanner. These results can be seen in Figure 5. The increase in beam width measured by the wire scanner is due to the horizontal emittance of the beam at the IPM position. A second period of machine physics, planned for October 2011, will be used to take more measurements from each of these monitors and to compare them with simulated results produced using the accelerator design code MAD [8].

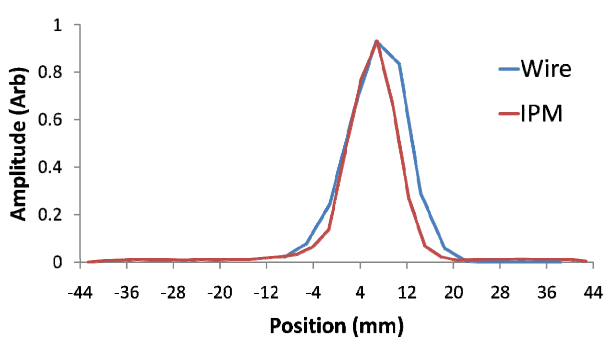

Figure 5: Beam profiles measured at the IPM and a wire scanner located ~1m downstream.

POTENTIAL FUTURE UPGRADES

Longitudinal Field Shape

The shaping electrodes provide a uniform electric field gradient transverse to the beam direction but they do not address the longitudinal field shape along the beam axis. Previous work [9], and computer simulations reported in this paper, using CST EM Studio software, show that improvements in the longitudinal field could be made with the addition of 'corrector' electrodes as shown in Figure 6.

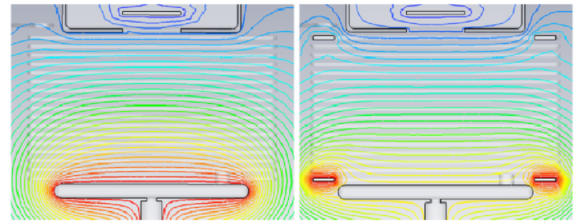

Figure 6: Longitudinal field within the IPM field shaping electrodes, without (left) and with (right) the longitudinal field corrector electrodes

SUMMARY

A new non destructive MCP based gas ionisation profile monitor has been installed in the HEDS line of the ISIS H^- Injector. The new monitor has proven very successful in measuring beam profile data in real time and under normal ISIS operating conditions; something not possible with the existing scanning wire monitors. Early comparisons of beam profile data, using low intensity H^- beams, between the new diagnostic and a nearby scanning wire profile monitor are extremely encouraging.

The calibration system which involves rotating the MCP parallel to the beam has been shown to remove the gain variations that exist across the MCP. The calibration method will extend the useful lifetime of the diagnostic by also removing gain variations due to aging. Computer simulations of the longitudinal fields have shown that the linearity can be improved with the addition of transverse corrector electrodes.

REFERENCES

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