FIRST TEST RESULTS FOR A RESIDUAL GAS BEAM PROFILE MONITOR

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Abstract

A Residual Gas Beam Profile Monitor (RG-BPM) has been designed to study the cooling process of an ion beam circulating in a storage ring where the residual gas has a very low pressure. In this case the residual gas ion rate is very low and a single ion counting technique is required to reconstruct the beam profile. The peculiar feature of this device is the read-out system that can lead to a sensitive improvement of the spatial resolution. The same device can work also in analog mode at higher residual gas pressure and, then, it can be used also for other kind of accelerators. The test of the RG-BPM on an ion beam from an electrostatic accelerator is here given. The preliminary test arrangement for the ion single counting mode is also presented.

1 INTRODUCTION

Powerful non-destructive diagnostic methods based on the residual gas ionization produced by the ion beam has been developed and used on several accelerators [1,2]. In these devices the residual gas ions produced by the beam are collected, detected and spatially resolved in certain point of the accelerator by applying a transverse electric field plus a position sensitive detector. This kind of device is very helpful for any type of accelarator but it is of great importance for studing beam cooling in ion storage ring. However the high vacuum needed ($< 10^{-11}$ mbar) for the storage ring operation leads to a very low residual gas ion production rate. This drawback has been overcome by using a vapor target to increase, locally, the background gas density. However, this technique perturbs the beam and if high quality beams are wanted it is no more useful.

Recently a new type of Residual Gas Beam Profile Monitor (RG-BPM) has been designed and constructed [3]. The device can employ a single-particle counting technique (counting mode) to increase the sensitivity of the detection in case of ultra high vacuum, as in the ion storage rings. The analog mode of operation is usually employed in single pass beams where the pressure of beam lines are of the order of 10^{-6}-10^{-8} mbar.
In this work the first test result of this device used in analog mode on the Legnaro Tandem accelerator ion beam is presented. Furtermore the experimental set-up of the counting mode test, where an alfa particle radioactive source will be used, is also shown.

2 THE RG-BPM

The working principle of a RG-BPM and its detailed design has been already presented in ref.3. For sake of clearness we present here, again, the operation scheme and shortly recall the main features of the device. The operation scheme, with its electric connections, is shown in fig. 1. PS1, PS2, PS3, PS4 are the Power supplies. The transverse electric field needed to accelerate the residual gas ion toward the MCP is given by the high voltage generator PS1 (16 kV) and PS2 (-4kV). The lower face voltage of MCP is given by PS3 and the upper face by PS4. The four power supplies allow of changing the voltage between the MCP faces and with respect to the phosphor screen in an independent way. In this way one can increase or decrease the voltage difference between the two stage MCP and then change the MCP gain. In this way, a suitable output signal for very different residual gas ion production rates can be obtained allowing the detector to be active in a wide range of beam currents.

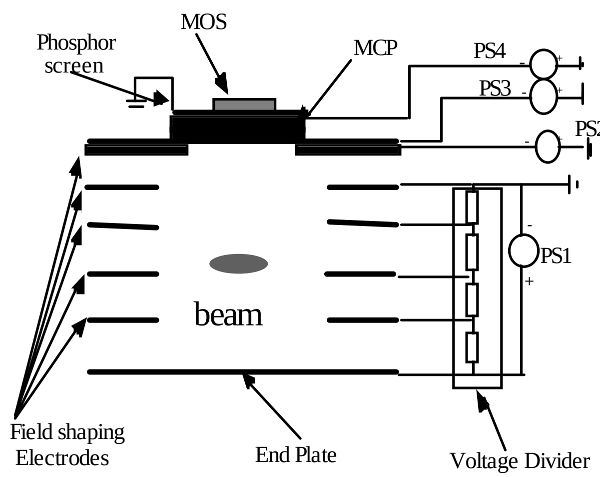

Fig.1 Operation scheme of RG-BPM.

The transvere electric field conveys the residual gas ions towards the lower face of MCP. At the exit of the two MCP stages a current of electrons proportional to the number of collected ions is produced. The electrons are accelerated towards the phosphor screen that emits a light spot which is detected by the MOS sensor. The MOS and the Phosphor screen are coupled by a Fiber Optic Plates (FOP). Compared to the lens coupling, this tecnique offers advantages such as high light transmission efficiency and compactness.

The MOS linear image sensor is a self-scanning linear photodiode array with a single video output line [4]. These kinds of sensors have a wide photosensitive area with a pixel height of 2.5 mm, a pixel pitch of 25 μm and a number of pixel of 1024. It has a high sensitivity in the range 500-800 nm, which is close to the spectral emission of the P-20 phosphor peaked at about 550 nm.

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The ion production rate depends on the product of the vacuum pressure and beam current. Since on the test beam line the vacuum pressure is about 10^{-7} mbar and the ion beam current is of some particle-nano-Amperes, then a residual gas ion production rate sufficient to an analog mode operation is expected [5]. In this mode of operation typical MCP multiplication factor is kept in the approximate range of 10^{2} to 10^{4} to prevent charge saturation in the MCP channels.

Fig.2 shows the profile of a Au ion beam from the LNL tandem (230 MeV, 3 p-nA) obtained with the RG-BPM under test in analog mode.

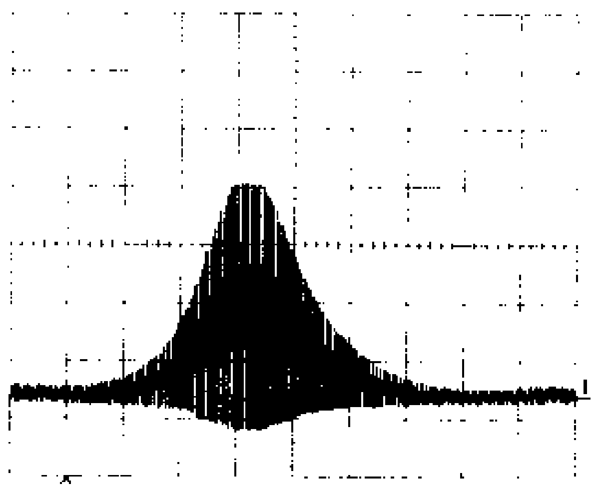

Fig.2. Ion beam profile given by the RG-BPM as seen on an oscilloscope screen; electronic noise: 500 mV.
(2 V/div, 1 ms/div equivalent to 3 mm/div in transverse space).

Just in front to the lower face of the MCP, two calibration wires were placed at a distance of 3 mm each others. The two wire shadows were visible by eyes trough the FOP, but, as it can be seen in the fig.2, they are not visible on the oscilloscope screen. The reason of this could be related to an insufficient optical coupling between the exit of the FOP and the entrance of the MOS sensor. Actually there is still a distance of about 1 mm between the FOP plane and the MOS face, causing a widining of the spot light. In this conditions the light exiting from the FOP has enough space to spread on the MOS and then the wire shadows on the MOS pixels are cancelled. To improve the coupling between the FOP and the MOS pixels the distance between them have to be reduced to less than 100 μm. The above considerations can suggest that the output shown in fig. 2 can suffer from this widening.

3 COUNTING MODE OPERATION

With very low ion production (very low currents or vacuum pressure below 10^{-9} mbar), a single particle detection is nedeed.

When at the MCP faces a voltage difference of 1.8 kV is applied, the MCP gain reach a value of 10^{6}. In this conditon a single particle impinging onto the lower face of MCP gives on the phosphor screen a light spot representing individual ion that can be detected by the MOS sensor [4].

Since, under these conditions, the MCP multiplication is saturated, these light spots have uniform intensity. Therefore the amplitude of the output signal is constant and not correlated to the density in transverse space. This mode of operation is called “counting mode”. The transverse beam profile, is reconstructed recording in a frame memory the number of hits vs position of the light spots.

In fig.3 the block diagram of the experimental set-up to test the RG-BPM in counting mode is shown.

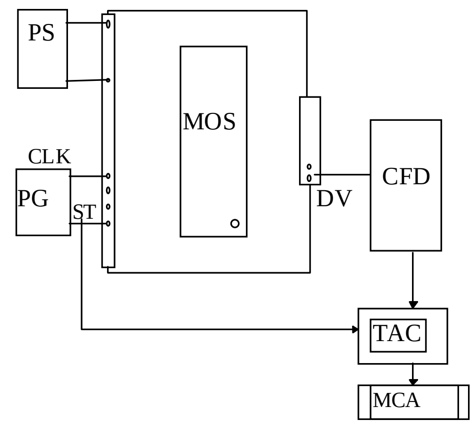

Fig.3 Block diagram of the experimental set-up for the counting mode operation of the RG-BPM: (PS) Power Supply, (PG) Pulse Generator, (CFD) Constant Fraction Discriminator, (TAC) Time to Amplitude Converter, (MCA), Multi-Channel Analyser.

DV (Data Video) is the MOS output signal generated by the self scanning shift-register, composed by the succession of the signals of each pixel [4].

The CFD is a level discriminator with a threshold set slightly above the noise signal, the logical output is used as the stop signal on a Time to Amplitude Converter module. CLK and ST are, respectively, the clock and the start signal needed to drive the MOS sensor. The ST signal is also used as start for the TAC.

The output signals of the TAC are collected and recorded on a Multi Channel Analyzer

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