PERFORMANCE OF THE SCINTILLATION PROFILE MONITOR IN THE COSY SYNCHROTRON

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Abstract

Residual gas scintillation is used for measuring profile of the proton beam circulating in the COSY synchrotron. The problem of low rate of scintillation events detected by a multichannel photomultiplier is coped with by injecting small amounts of pure nitrogen into the vacuum chamber of the Scintillation Profile Monitor (SPM). This leads to a temporary local pressure bump of no more than an order of magnitude. A commercially available piezo-electric dosing valve allows good control over the amplitude and duration of the pressure bump. Since the average pressure in the machine is hardly changed, the method is fully compatible with experiment operation. This approach offers a robust and inexpensive way to measure the beam profile. The design of the SPM is discussed. The latest measurement results and comparison to the ionization profile monitor data is presented.

INTRODUCTION

Beam profile monitoring is essential for emittance control and general performance optimization in an accelerator. Unlike linear accelerators the beam emittance in a circular machine can be determined using non-destructive techniques only. At COSY [1], a machine equipped with electron cooler and stochastic cooling system, profile data is vital for studies of the cooling process. A joint effort by the beam instrumentation groups at GSI, Darmstadt and COSY, Jülich resulted in an Ionization Profile Monitors (IPM) being operational at ESR [2] and COSY [3]. The IPM was designed to become a standard profile monitor for the future FAIR [4] machines. The IPMs real time performance together with high sensitivity and resolution make it a very valuable instrument. However, high cost and presence of components prone to aging in vacuum, triggered the search for alternative methods. A profile monitor utilizing scintillation of residual gas offers a viable alternative to an IPM for certain beam conditions [5, 6]. The gas atoms and molecules are excited by the beam particles and emit visible light shortly after the excitation [7]. After passing a vacuum window the light is focused by an optical system and is detected by a multi-channel photomultiplier or an image intensified camera. Measuring the photon distribution allows reconstructing the initial beam profile.

SPM IN A PROTON SYNCHROTRON

Challenges

Compared to the ionization event rate, the rate of scintillation events is expected to be three orders of magnitude lower [8]. The reasons are the lower scintillation cross section and the geometrical factor. Nearly all ions/electrons can be collected in an IPM but only a fraction of light reaches the detector in an SPM [8]. Furthermore, vacuum conditions in a proton synchrotron like COSY cause the scintillation signal to disappear in the background noise.

At average COSY vacuum of 10^{-9} mbar no SPM measurements are possible. When internal targets (mostly hydrogen) are in operation the residual gas pressure can reach values beyond 10^{-7} mbar in the target region of the machine. Unfortunately this pressure bumps cannot be used for profile measurement. Nitrogen was found to be the most suitable gas [7, 9]. To increase the signal to noise ratio a local nitrogen pressure bump is introduced.

Advantages

A scintillation profile monitor does not require any vacuum parts except for vacuum windows which makes it a simple, inexpensive and robust instrument. Being based on light, the technique is insensitive to the electric and magnetic fields in the vacuum chamber (e.g. beam space charge). Furthermore, the light can be transported outside the accelerator tunnel if necessary. This is particularly important for high intensity machines where high radiation levels make installation of electronics in the tunnel difficult.

The Setup

The SPM vacuum chamber installed in COSY has a length of 508 mm [10]. The inner diameter of 150 mm corresponds to the inner diameter of COSY beam pipe in straight sections . To avoid possible light reflection the inner surface of the vacuum chamber was acid cleaned to increase the roughness and then blackened by chemical treatment. The chamber is equipped with two DN100 vacuum windows and two DN40 vacuum ports for pressure measurement and gas inlet. To create local pressure bumps a commercially available piezo-electric dosing valve is used. The piezo stack is driven by a 1 kV power supply purchased from the same company. After passing the vacuum window the light is focused by a lens and detected by a 32-channel photomultiplier. The SPM is currently equipped with one detector only measuring horizontal profiles. The calibration in mm is based on the assumption that the vertical position of the beam corresponds to the geometrical center of the vacuum chamber. The PMT readout is done by a 48-channel picoammeter module developed by iThemba Labs, South Africa [6]. The module design is based on a commercially available low noise switched integrator chip. The PMT power supply and readout module as well as dosing valve power supply are controlled and/or read out over local Ethernet. The latter requires an Ethernet to RS-232

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converter. The control and data acquisition software is written in LabView.

MEASUREMENT RESULTS

The SPM measurement procedure is described in [10]. Fig. 1 shows the profiles measured with the SPM (top plot) and the IPM (lower plot) at the same time. The measurement was carried out during ANKE beam time with polarized deuterons on July 8, 2011. While the SPM is installed in the target telescope the IPM is located in the arc downstream the cooler telescope. To compare the profiles beta functions obtained from the COSY model were used. According to the model the estimated horizontal beta function at the IPM location is about factor 2 larger than the one at the SPM location. So the width of the SPM profile is expected to be smaller than the width of the IPM one. As Fig. 1 shows this is not the case. We observe a significant discrepancy from the expected value. The origin of the discrepancy is not identified yet. The measurement was carried out at beam intensity of $1{\cdot}10^{10}$ deuterons in the machine during stacking process accompanied by electron cooling. The PMT voltage was set to 700 V.

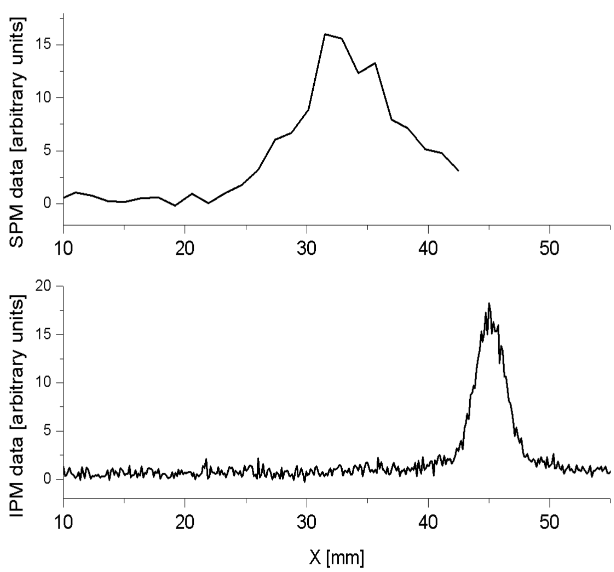

Figure 1: Comparison of the horizontal beam profiles acquired by the SPM (top plot) and the IPM (lower plot).

SUMMARY

The measurements performed at COSY have shown that a profile monitor based on gas scintillation can achieve good signal to noise ratios in a proton synchrotron. However, first comparison of the SPM data with the IPM one revealed a significant discrepancy. The deviation is too large to be explained by the beam being out of focus of the SPM optics. The origin of the discrepancy is still to be understood. The SPM optics and the model data need to be verified. The effect of ionization products, presence of different gases in the vacuum chamber, issues possibly related to the cooling and stacking process, influence of the injection orbit bumps as well as channel crosstalk in the PMT readout electronics are to be checked.

For COSY conditions a pressure bump was necessary at the monitor location to boost the scintillation event rate. The pressure bump was realized by injecting small amounts of pure nitrogen into the vacuum chamber by means of a piezo-electric dosing valve. Such a procedure was shown to be non-destructive for the beam. Some profile measurements were performed while experiments were taking data.

To better use the resolution capability of the multi-channel PMT and to be able to compensate for a beam position offset a motorized zoom lens with variable focus can be used.

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