

TOWARDS ROUTINE OPERATION OF THE SCINTILLATION PROFILE MONITOR AT COSY

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Abstract

The cooler synchrotron COSY is currently equipped with two non-destructive beam profile monitors. One is based on ionisation and the other on scintillation of residual gas. The optics of the Scintillation Profile Monitor (SPM) was modified to correct the large error observed in previous measurements. Beam profile measurements were carried out after reinstallation in the COSY ring, showing good agreement with profiles, measured with the Ionisation Profile Monitor (IPM). Performance of the SPM is analysed. Application of the method in a proton synchrotron is discussed.

INTRODUCTION

The COSY synchrotron is equipped with electron and stochastic cooling systems. The 100 kV electron cooler is used at low energies while stochastic cooling is applied at higher energies. Installation of the 2 MeV electron cooler, which is scheduled for the end of 2012, will allow for electron cooling in the entire energy range of COSY. Beam profile measurements are vital for the machine operation, in particular for setting up beam cooling. Profiles have to be measured without affecting the circulating beam. Two beam profile monitors are installed in COSY. The IPM is located in the arc downstream of the cooler telescope [1]. It delivers online beam profiles in both transverse planes and is used routinely for electron cooling optimisation. Very high sensitivity down to 10^8 particles in the ring at standard vacuum conditions (10^{-9} mbar) was demonstrated [2]. The SPM detects light emitted by residual gas excited by the beam particles. Though this technique is typically used in beamlines [3] or linacs [4], it can, with some limitations, be applied to a proton synchrotron. Average vacuum at COSY can vary from 10^{-10} to 5×10^{-9} mbar. However, at locations in the ring, where internal targets are operated, vacuum readings of the order of 10^{-7} mbar are not unusual. Unfortunately, installing a profile monitor at those locations is not possible.

Since the rate of detectable scintillation events at COSY is several orders of magnitude lower than the rate of ionisation events a local nitrogen pressure bump is used to achieve reasonable sensitivity. Naturally, this approach is not suitable for continuous profile monitoring in a synchrotron unless the duty cycle of gas injections is kept very low. A SPM can be very useful for periodically checking the beam profiles as machine performance verification or after changing some machine parameters.

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The main advantage of an SPM-like device is its simple and reliable design, low cost, high speed and insensitivity to electromagnetic fields (e.g. beam space charge). Additional advantages include a possibility to transport the scintillation light away from the beam pipe in case of high radiation environments. At an early stage of the SPM project profile measurements were performed at an external beamline in front of JESSICA, the COSY based ESS spallation target mock-up and moderator test bed.

SPM SETUP

The recently installed SPM vacuum chamber has two DN100-CF viewports for horizontal and vertical profile measurements and two DN40-CF ports for vacuum monitoring and gas injection. The chamber is blackened inside to suppress light reflection from the inner surface. A piezo-electric gas dosing valve is used for nitrogen injection into the SPM vacuum chamber. For first measurements single lens focusing was chosen to collect as much light as possible. The light is detected by a 32-channel photomultiplier which is read out by a multi-channel picoammeter electronics developed at iThemba LABS [3]. Fig. 1 shows the SPM optical setup. An adjustable lens tube is mounted directly on the viewport. The PMT enclosure is attached to the lens tube. For typical beam conditions at COSY, an additional iris had to be used to achieve a reasonable depth of field.

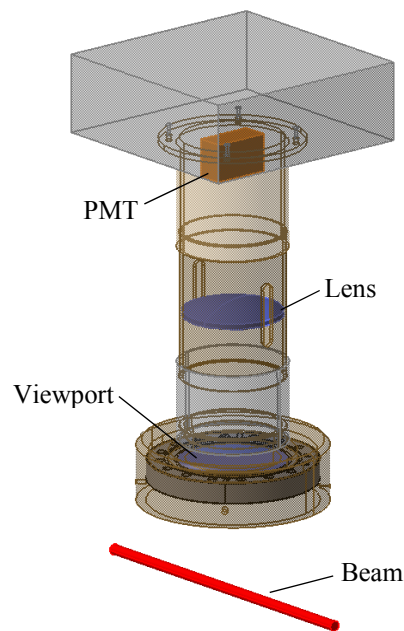


Figure 1: SPM setup. Vacuum chamber is not shown.

PROFILE MEASUREMENTS

A local pressure bump is introduced for the duration of profile measurement to increase scintillation light intensity for the SPM. Nitrogen injection is done by means of a commercially available piezo-electric valve. At 4×10^{-8} mbar and beam intensities of the order of 5×10^9 protons in the ring reasonable S/N ratio is achieved. The temporary pressure bumps did not have any impact on machine operation. Fig. 2 shows the measured beam profiles (top plot) as the proton beam was being cooled.

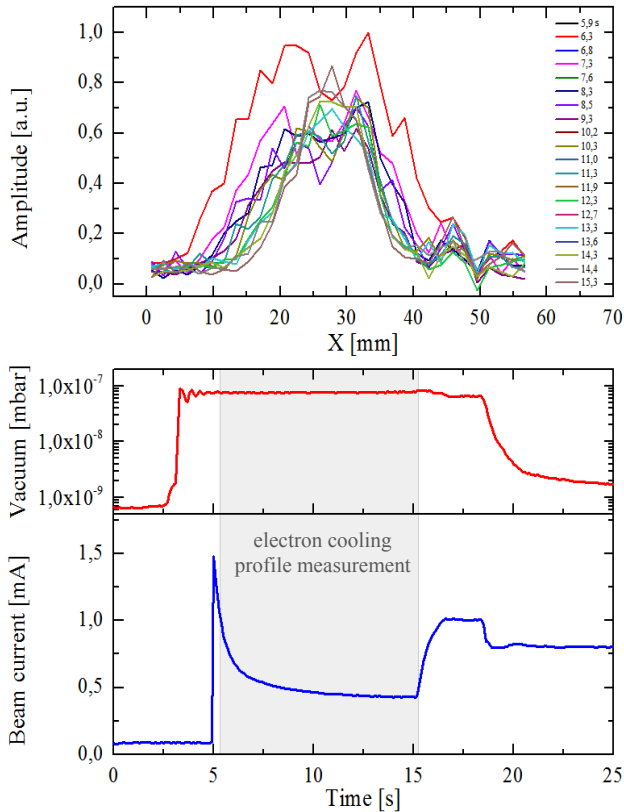


Figure 2: Horizontal beam profiles measured with the SPM (top plot), vacuum reading (centre plot) and beam current (lower plot).

The lower plot shows the beam current. The injection occurred at $t = 5s$ and was followed by 10s of electron cooling (accompanied by beam losses). The beam was then accelerated and slowly extracted from the ring to an external experiment. Profile data was recorded during electron cooling at injection energy only (5.9s – 15.3s). Beam shrinking due to cooling is clearly seen. SPM performance was verified by comparing measured profiles with the IPM results. Fig. 3 shows the horizontal SPM and IPM beam widths and beam current plotted over time. The data was taken as the proton beam was cooled at injection energy. The SPM data was scaled according to COSY optics model to allow comparison. This measurement shows good agreement between SPM and IPM data.

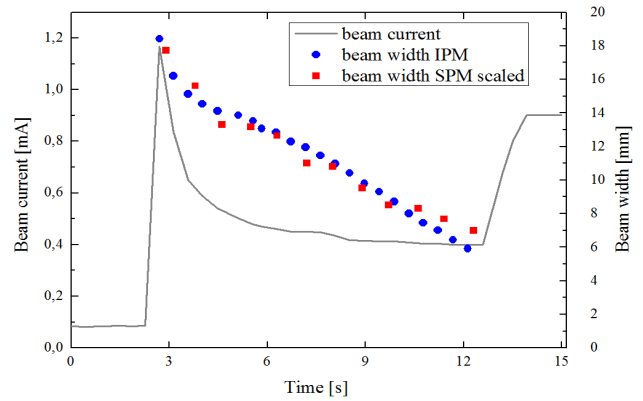


Figure 3: Comparison of SPM and IPM measurements. Plotted are horizontal 1σ beam widths measured by SPM and IPM and beam current. The SPM data is scaled using COSY model ($\beta_{SPM} = 6.5m$, $\beta_{IPM} = 14.2m$). Beam profiles were recorded at injection energy during electron cooling.

SPM UPGRADE

Although successful beam profile measurements could be performed using current SPM setup, some issues need to be resolved to enable routine operation. Given a fixed lens position and an aperture value a certain spatial region inside the vacuum chamber can be imaged without blurring. Currently the system relies upon the beam position and width being within this region. This may not always be the case. A redesign of the optical system is in progress to achieve better sensitivity and resolution by motorized adjustment of optical elements to the beam position and width. Fig. 4 shows the optics design being considered. The use of single lenses as well as compound lenses is foreseen. An electron cooled beam would require much less depth of field compared with uncooled one, so bigger aperture can be used allowing for higher sensitivity. Zooming functionality will allow for optimal use of available 32 channels.

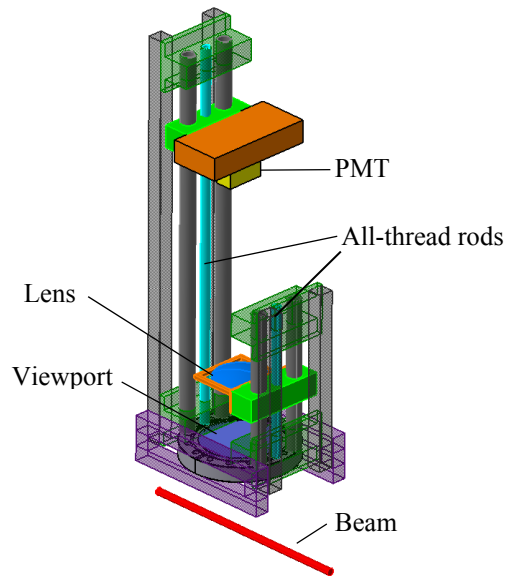


Figure 4: Motorised optics for SPM. Design under consideration. Beam pipe and motor drives are not shown.

SUMMARY

Horizontal beam profiles were measured in COSY using scintillation of residual gas. Good agreement is demonstrated between SPM and IPM. SPM upgrade is on the way to make the instrument suitable for routine operation.

ACKNOWLEDGMENT

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