BEAM PROFILE MONITORING AT COSY VIA LIGHT EMITTED BY RESIDUAL GAS*

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Abstract

Scintillation is one of the outcomes of beam interaction with residual gas. This process is utilized for non-destructive beam profile monitoring. Test bench measurements at various gas compositions and pressures have been performed, as well as measurements at the 3.14 MeV cyclotron beam line at iThemba LABS as well as ones with the circulating proton beam at COSY-Juelich. The test bench measurements have been mainly done using a single large photocathode photomultiplier to estimate the photon yield. A multichannel photomultiplier was used along with a lens system to monitor the ion beam profile at iThemba LABS. Experimental results are presented and the challenges of the approach are discussed.

INTRODUCTION

The knowledge of the beam position and profile is essential for the successful operation of an accelerator facility. At hadron accelerators the high beam current limits the use of traditional intersecting methods like wire scanners or secondary electron emission (SEM) grids, because the used materials are heated or melted trough the beam energy. At synchrotrons non destructive methods are preferred to monitor the circulating beam. Several kinds of diagnostic devices, using the products of the interaction between the ion beam and the residual gas, are under development or in use. Usually the devices register the ions and/or electrons produced in collisions of the beam particles with the residual gas. Some attempts have already been made which use the emitted light of the excited residual gas atoms in order to monitor the beam [1]. This method of registering photons has the advantage of being insensitive to electric or magnetic fields. Also the spatial and time resolution is considerably higher, allowing a single pulse measurement. The limitation of this method is the cross section of light emission, which is about three orders of magnitude lower compared to ionization. Nevertheless, a wide range of applications can still be covered with this method.

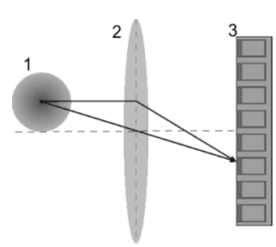

Figure 1: Measurement principle (not to scale): The light from the beam (1) is focused with a glass lens (2) onto the multichannel photomultiplier (3).

MEASUREMENT TECHNIQUE

The light emitted by the residual gas is focused by a glass lens onto a position sensitive multichannel photo-multiplier (PMT) array, as shown in Figure 1. A Hamamatsu PMT (7260-type, 32 channels, 0.7·10 mm photocathode size, 1mm pitch size) was used for the position sensitive measurements. Along with that, a Philips XP2020 single channel PMT (44mm round photocathode) was used for basic research, mainly without an optical lens system in order to have a large aperture angle for the registration of photons. Depending on the amount of photons registered the readout of the PMT was adapted. For low intensities a discriminator was used together with a counter, in order to count the number of events. For high intensities a direct current measurement was performed using a 48 multichannel current digitizer, developed at iThemba LABS.

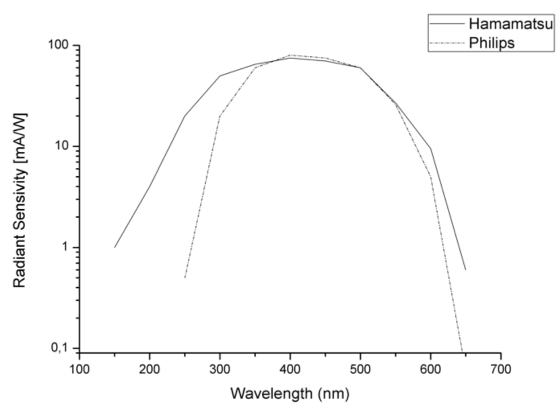

Figure 2: Luminous characteristics of the Photomultipliers used.

PHOTON YIELD

While measuring the beam profile using photons emitted by the residual gas the only controllable parameters of

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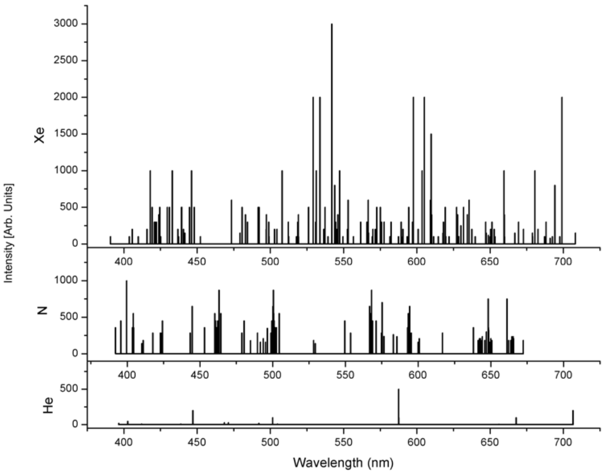

Figure 3: Expected wavelength distribution within the visible range of the investigated gases [3].

the photon yield are the composition and pressure of the residual gas at a given ion beam parameters. Along with the residual gas, one possibility is to intentionally increase the gas pressure in order to increase the photon yield. Although the increase of residual gas pressure is normally not applicable in accelerators and especially within synchrotrons, as the beam passes the region of high pressure many times possibly resulting in emittance increase, it has been successfully tested [2]. While the residual gas mixture is given, the gas to be added can be chosen within certain limits. Two gases are candidates for addition, N_2 and Xe. These gases are used, because both show strong light emission within the visible range (see figure 3) and are also easily pumped out of the vacuum system by the pumps.

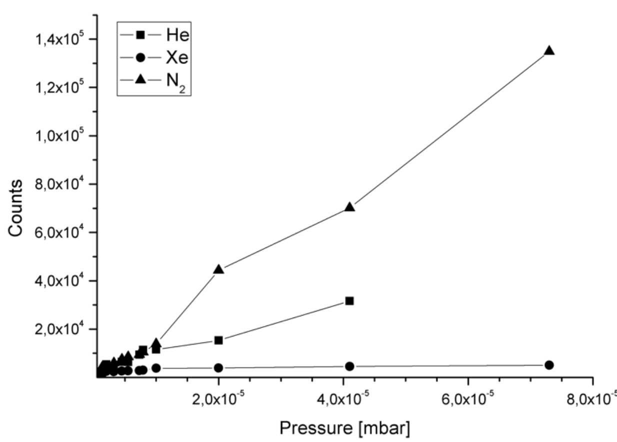

Figure 4: Photon yield for different gas pressures for He (●), N_2 (▲) and Xe (■) at 12keV He ion beam.

Test Bench Measurements

In order to test and enhance the measurement setup before installing it in the synchrotron, a test bench was used. Here the pressure can be varied between about $5 \cdot 10^{-7}$ and $1 \cdot 10^{-4}$ mbar. The test bench is equipped with an ion source which can generate Helium ions up to 20 keV. The experiments have been performed in a special chamber which has been darkened inside to minimize reflections. Upstream the PMT setup a emittance measuring device is installed. This can be used to determine the beam characteristics.

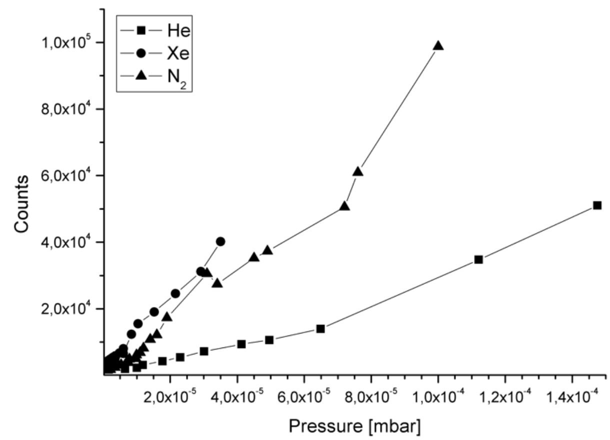

Figure 5: Photon yield for different gas pressures for He (●), N_2 (▲) and Xe (■) at 6keV He ion beam.

With this setup the light production rate with the described gases has been tested at several pressures and for different ion energies. The light emission of helium was also measured, for reference purposes, as helium, which is used in the ion source of the facility, causes a background. The results are shown at Figure 4 and Figure 5. The photon yield shows a linear dependence on gas pressure. Since the cross sections for excitation of the measured gases with protons and Helium ions show different behavior [4], these measurements cannot be transferred directly to experiments within COSY.

Profile Measurements in the Cyclotron Beamline at Low Energies

Measurements were performed at the iThemba LABS cyclotron beamline with a 3.14 MeV proton beam at a residual gas pressure of 10^{-5} mbar and about 300 μA beam current [6]. The Hamamatsu multichannel PMT was connected to the multichannel current digitizer, allowing to take data from all channels simultaniously. The beam position is measured for reference by two BPMs, placed upstream and downstream of the PMT. The beam was deflected with a steering magnet to verify if the position change reported by the BPMs agrees with the PMT measurement. In Figure 6 the measured data is shown together with a Gaussian fit for each measurement. The results of the PMT measurement are in good agreement with the BPM measurement.

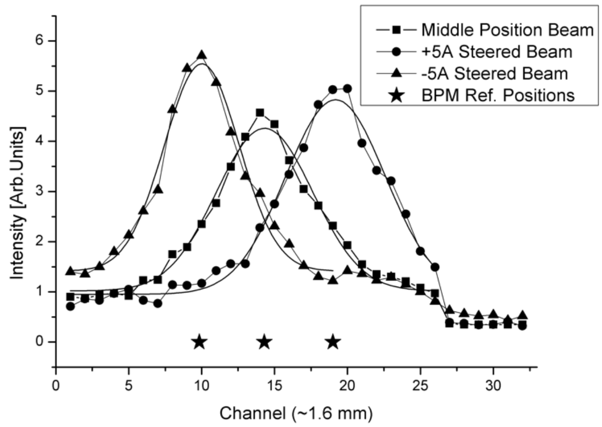

Figure 6: Profile measurements for a 3.14 MeV proton beam shifted with a steerer. The BPMs middle position is adjusted to fit the PMTs one. The channels on the right side are darkened for background measurement.

Measurements in a Synchrotron

To evaluate whether the method is practical for usage in a synchrotron, the multichannel PMT has been installed at COSY Juelich. First measurements have already been reported in [5]. Further measurements had been planned to take place in the proximity to an internal experiment using a gas target. Unfortunately, these measurements could not be completed, because of a strong light background of which the source could not be localized.

CONCLUSIONS

The presented method of monitoring beam profiles with residual gas scintillation seems to be promising. The method has been successfully used at different setups, e.g. the iTemba LABS cyclotron beamline, the JESSICA experiment at COSY Juelich in preparation of the ESS, and also first measurements at the COSY synchrotron have been made, although the original goal of single turn measurements in a synchrotron has not been achieved yet. During the tests the instrumentation was improved, with the current digitizer developed at iThemba labs the readout of the 32 channels is easily possible, even at low light conditions where usually photon counting methods, discriminators combined with counters, would be used. For testing and improving the instrumentation the dedicated test bench has proven to be very useful. One of the next steps is the use of cylindrical lenses to make use of a larger solid angle of the beam. Another possibility would be to generate a fast local pressure bump, which will be tested at COSY Juelich in near future.

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