Analysis of the Proton Beam in the DESY Transport Lines by Video Readout

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Abstract

Injection efficiency, beam optic matching and emittance preservation are very important parameters in achieving a high luminosity in large proton accelerators. We improved the analysing system of the phosphor screen readout of the proton transport lines in the accelerator chain of HERA with respect to the parameters above. The screens are read out by simple CCD video cameras. The signals are stored in local frame grabbers. An analogue output of the stored image is multiplexed and read-out by a fast PCI frame grabber card in a PC. The beam orbit and the beam emittance can be measured from each screen. A Visual Basic program is used to displays the trajectory and the envelope of the beam from a single transfer. The same program helps to drive bumps to achieve a proper steering through the line. The beam width can be measured from selected screens to calculate the emittance and other beam parameters including their errors. The read out and analysing system will be described and measurements will be shown.

1 INTRODUCTION

The Position and shape of the proton beam is observed in all transfer lines by thin luminescence screens read-out by TV video cameras (12 screens in the transport line from DESY III to PETRA (P-line) and 20 screens in the line between PETRA and HERA (PR-line)). Some cameras of the PR line were connected to a in-house developed local frame grabber, triggered by the transfer of protons to display a visible spot of a selected screen on a TV screen in the control room. The centre of gravity was determined in this system using all the light detected by the camera, including reflections. This led to large errors in the position measurement due to background problems. A measurement of the beam size was not foreseen.

This old system has been upgraded with new hardware and software (see Fig. 1): 12 new local frame grabbers (Model MBS, Compulog) were installed in the P-line, observing the adjacent 12 screens. They store the two TV-frames following a transfer-trigger. Both grabber types provides an analogue TV output of the stored frames. The analogue signals are connected to two video multiplexers, one for each transport line. A dedicated PC containing a fast PCI frame grabber card (Type: DT3155, Data Translation) is used to control the multiplexers and to collect and analyse all frames from

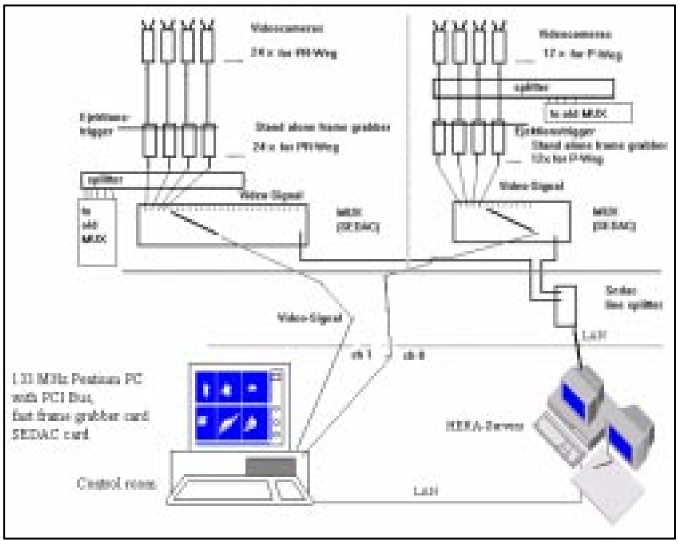

Figure 1: Layout of the readout scheme

one transfer. This provides a fast analysis of the TV signals without the traffic on the local area network (LAN) of the control system which would otherwise be needed to transfer all the frames though the LAN.

2 POSITION MEASUREMENT AND ORBIT CORRECTION

Fig. 2 shows a typical TV image of a screen stored after a beam transfer. The measured positions of the beam are displayed graphically in a Visual Basic program which provides full control of the screens, camera readout and correction magnets. Fig. 3 shows a

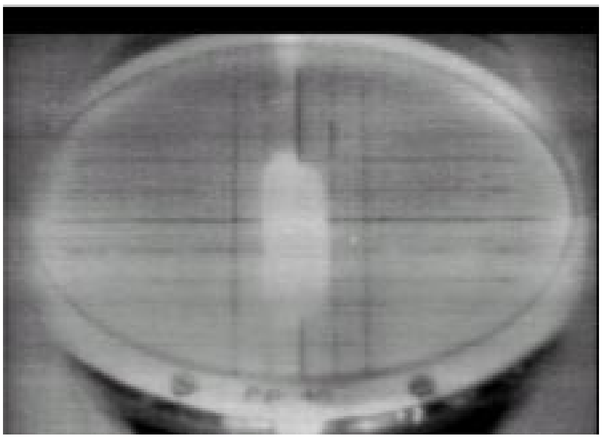

Fig. 2: Beam spot on a screen. The screen is illuminated by an external light source

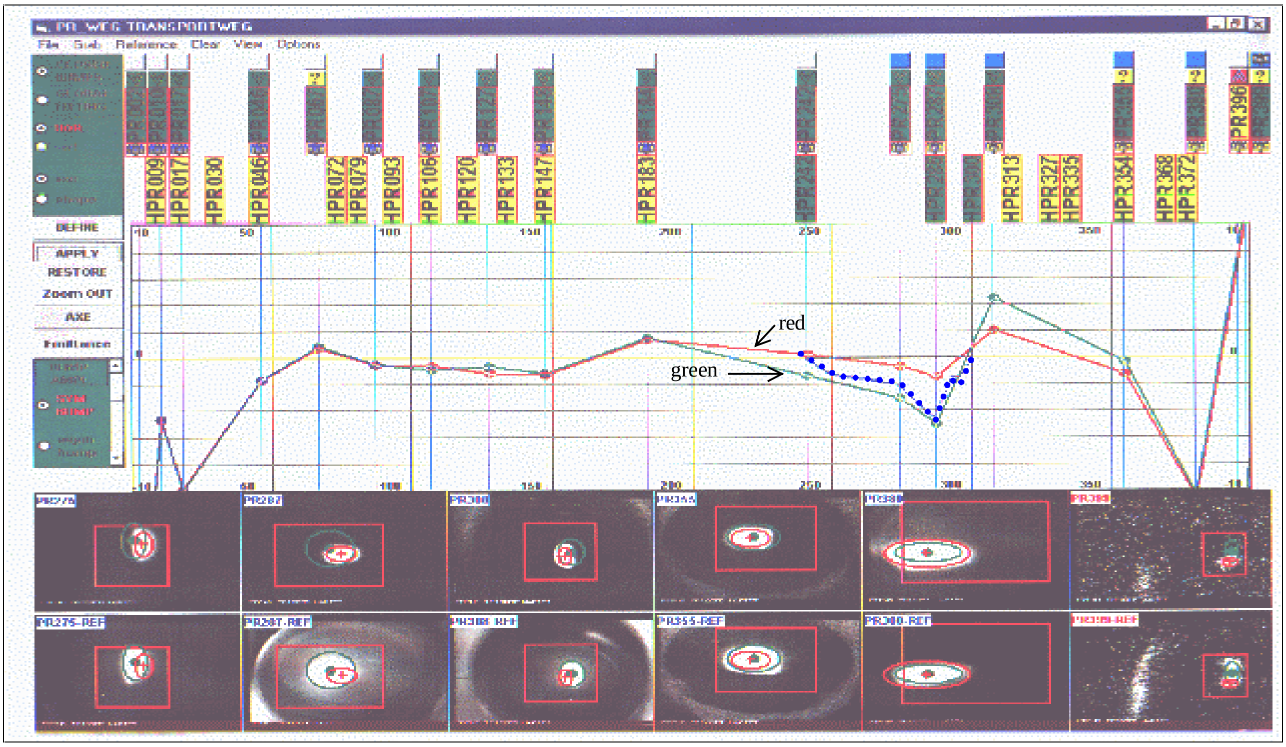

Fig.3: Display of the PR-line Visual Basic Program

display of the program. The two rows on top indicate the screens and the correction coils (the horizontal plane is shown). Each screen and coil can be activated for orbit measurements and corrections. In this example, a local bump is used to correct an orbit deviation. The green trace shows a big excursion (-5 mm) of the beam in this region before applying the bump. Three coils have been activated (dark) to apply a closed bump. The blue (dotted) line indicates the bump needed to correct the excursion. Note that it has to be on top of the deviated orbit to correct the orbit. The red line shows the measured orbit after applying the bump. A fairly good correction was achieved. [1]

The activated screens are shown beneath the orbit window (first row) together with saved reference pictures (second row). The operator can specify a region of interest (red box) for each picture. This feature allows to calculate the position of the beam inside the selected region only, which is helpful for the analysis of noisy pictures: A pixel for pixel subtraction of a stored background reference (made without beam) is done first for each individual image. The position of the beam is determined by the centre of a gaussian fit to the beam profile which was found to be more precise than the centre of gravity method. The centre of the beam (+ and • for reference) and a FWHM line from the gaussian fit is displayed.

[1] The operator can select a single coil, a closed bump or a desired orbit excursion. In the last case the program calculates a superposition of closed bumps which fits best to

The reproducibility of the position measurement from shot to shot is better than 0.5 mm. The absolute beam position relies on reference marks on the screen and on the positions of the screens in the vacuum chamber and is probably not better than 1-2 mm. However, after optimising a transport line for maximum efficiency, a good reference orbit can be saves in a reference database and used to compare with actual orbits. This provides a simple and fast way to setup and maintain the transport lines for maximum efficiency.

3 PROFILE MEASUREMENTS

The beam image on the screen can also be used to determine the beam size and its emittance. Projections of the region of interest of the video signal result in the (vertical and horizontal) profiles of the spot. Profiles are shown in Fig. 3 together with gaussian fits. Unfortunately many of the screens suffer from saturation of the TV camera signal at full beam intensity which results in large errors in the beam size measurements. Therefore a remotely controllable diaphragm has been installed in front of a few CCD cameras to reduce the amount of light. Reliable profiles could then be measured with emittances consistent with those measured in the circular accelerators. But the diaphragm is typically smaller than 1 mm. Therefore diffraction may broaden the measured profile. Neutral density filters, which may be a better solution, are foreseen in the future. At the moment, the emittance determination relies on the theoretical optical parameters of the transport lines.

For the future it is planed to use more than 4 screens in the line to measure all optical parameters together with their errors within one transfer [1].

The program displays the measured width of all screens together with the theoretical beam envelope. Fig. 4. shows such a measurement for the p-line. This view gives immediately a hint to the operator at which location a better orbit steering may increase the efficiency of the transport line by reducing the overlap of the aperture and the beam envelope. Again, the two rows on top indicate the screens and correction coils. The activated screens are shown beneath the orbit window. The beam envelope and the measured size (FWHM) are shown in the middle, together with the aperture limits of the transport line. A line at the positions of the screens indicates the measured beam size. This time, all signals were saturated and show a much bigger size than the theoretical envelope except for screen at 186 m, which is in agreement with the expectation.

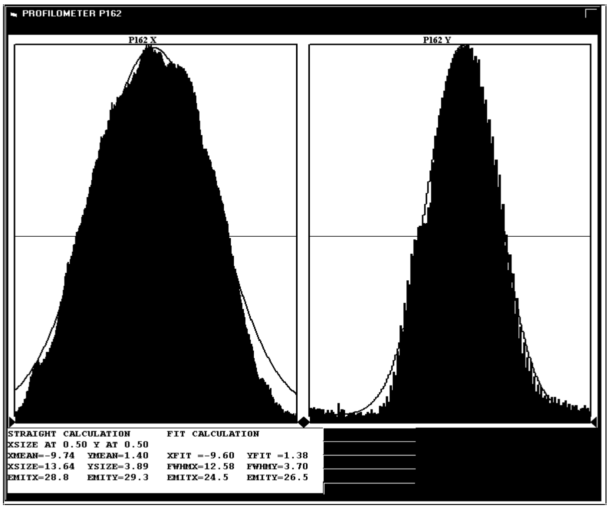

Fig. 3: Horizontal and vertical Profile of the screen 162 in the P-line (after installation of a diaphragm)

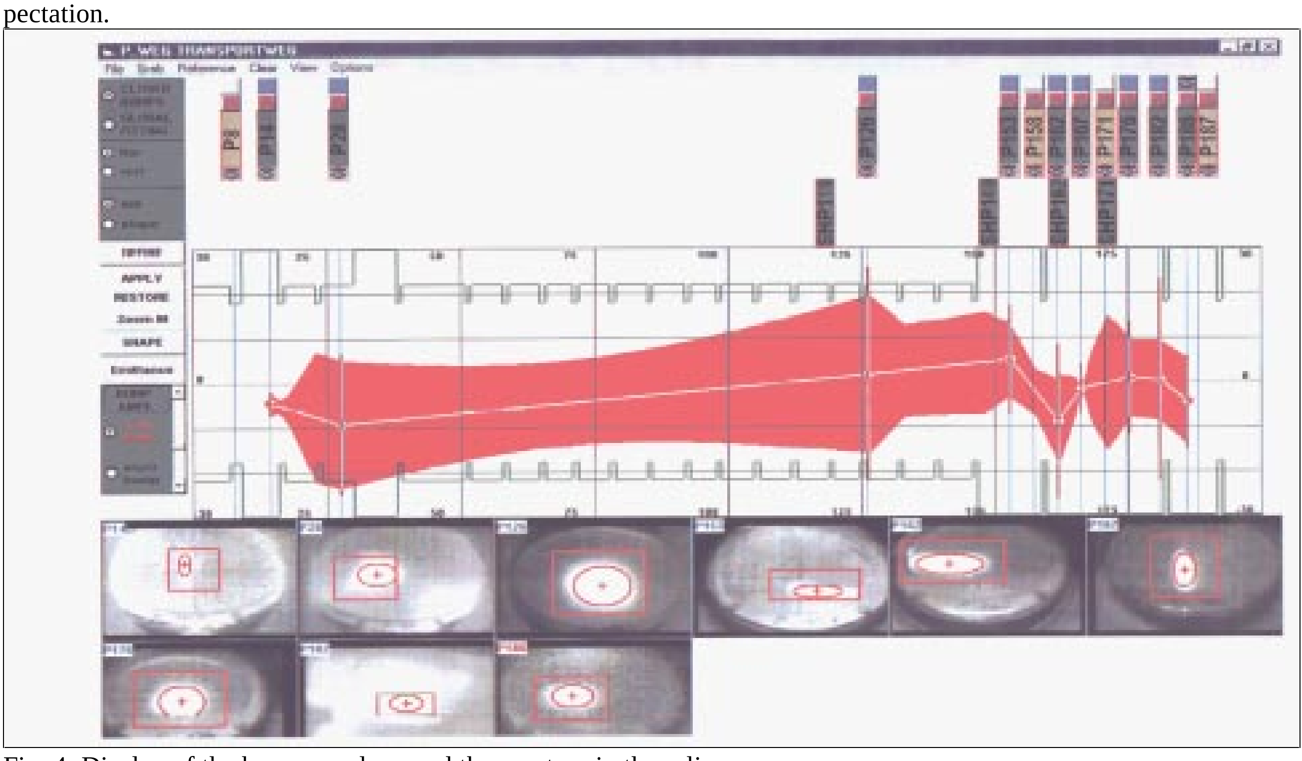

Fig. 4: Display of the beam envelope and the aperture in the p-line.

4 SUMMARY

The diagnostic for the proton transfer lines have been improved by using a simultaneous video grabbing scheme of the phosphor screens. A better analysis of the TV images is most helpful to achieve an optimal efficiency of the lines. To measure the emittance of the beam independent of the theoretical beam parameters by e.g. the 3 gradient method [2] or the position method, the quality of the TV signal needs an improvement, mainly saturation of the cameras has to be avoided.

ACKNOWLEDGEMENT

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REFERENCES

[1] G. Riehl et al., “Measurements of phase space dis-tributions”, DIPAC’95, Travemünde, May 1995.

[2] M.C. Ross et al., “Automated Emittance Measurements in the SLC”, Slac-Pub-42