Recycler Admittance Measurements

Martin Hu, Dan Broemmelsiek

1. Introduction

The admittance of an accelerator in one transverse dimension is defined as the area of the largest phase space ellipse associated with a beam that can be fitted into the beampipe[1]. We recall that the Courant-Snyder invariant, at any location in the accelerator, is

$$A^2 = \gamma x^2 + 2\alpha x x' + \beta x'^2,$$

where α, β and γ are the lattice parameters of the accelerator and x, x' are the phase space coordinates associated with one transverse dimension (Fig. 1). The phase space area of this ellipse is then

$$\frac{\pi A^2}{\sqrt{\gamma\beta - \alpha^2}} = \pi A^2,$$

since $\gamma\beta - \alpha^2 \equiv 1$.

The admittance of the accelerator can be measured at any one location in the accelerator provided that the half aperture, x_a, can be precisely determined, and the lattice function, β, is well understood at that location. Referring to Fig. 1, the measured half aperture,

$$x_a = A\sqrt{\beta},$$

and the phase space area, or the admittance of the accelerator, is

$$\frac{\pi x_a^2}{\beta}.$$

For a normalized admittance, the above quantity is multiplied by the factor $\beta_l \gamma_l$ associated with the Lorenz boost, which in the case of the Recycler (kinetic energy = 8 GeV) is 9.476.

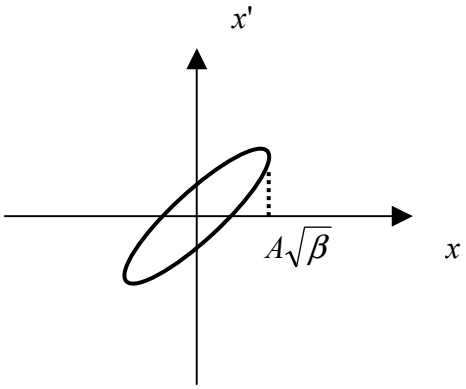

Figure 1: The phase space ellipse associated with one dimension at one location of the accelerator

2. Measurement of half aperture, x_a

The half aperture of the accelerator at one location can be measured with a scraping a beam away that has been heated to fill the aperture, provided that the precise position of the scraper, the initial point where the beam makes contact with the scraper, and the final point where the beam is totally extinguished are accurately known. In practice, beam is blown up transversely with the noise source [2] until at least 10% of loss has occurred; this ensures that the beam has filled the aperture of the accelerator. Beam is then scraped away with a mechanical scraper to measure the half aperture.

Figs. 2 and 3 show the beam current (R:IBEAMS), beam loss monitor (R:LMSP and R:LMVSP) and longitudinal Schottky zero span spectrum analyzer video output (R:LSVO) versus scraper position. This set of data was taken on Dec. 10th, 2001. The Main Injector ramping was paused throughout the duration of data taking. The beam current monitor is a DCCT type with sensitivity to 5 μA. The beam loss monitors are of the plastic scintillator type similar to those in the Antiproton Accumulator, which have been calibrated with a known gamma source to rather high sensitivity. The detail concerning the longitudinal Schottky can be found in [3]. The Schottky signal is fed into an HP spectrum analyzer at zero span; the video output of the SA then serves as an ultra sensitive beam current monitor. Corresponding data points are logged during the scrape so the data correlations can be reconstructed. Essentially, the distance between the initial beam loss position and the final position (the extinction point) is the half aperture, x_a.

As can be seen from Fig. 2, the half aperture is about 15 mm. The lattice function at the horizontal scraper is 52 meters [4]. The normalized horizontal admittance is then about 40 $\pi - mm - mrad$. Fig. 3 shows a vertical half aperture of about 13 mm. The lattice function at this location is 52 meters [4], and the normalized vertical admittance is then 30 $\pi - mm - mrad$. These numbers are subject to revision since an uncertainty of up to 20% in the scrapers' displacement will be addressed in the next available shutdown. In addition, efforts have been made continuously by the recycler staff to center the beam in the aperture, which will have an effect of increasing the admittances of the recycler.

6. References

[1] D.A. Edwards and M.J. Syphers, "An Introduction to the Physics of High Energy Accelerators", John Wiley and Sons, 1993

[2] E. Cullerton and M. Hu, "The Recycler Noise Source and Its Application", MI note xx, 2002

[3] E. Cullerton and M. Hu, "Longitudinal Schottky Pickup for the Recycler", MI note xx, 2002

[4] M. Yang and D. Johnson, TBT lattice function measurements and MAD modelling, private communications

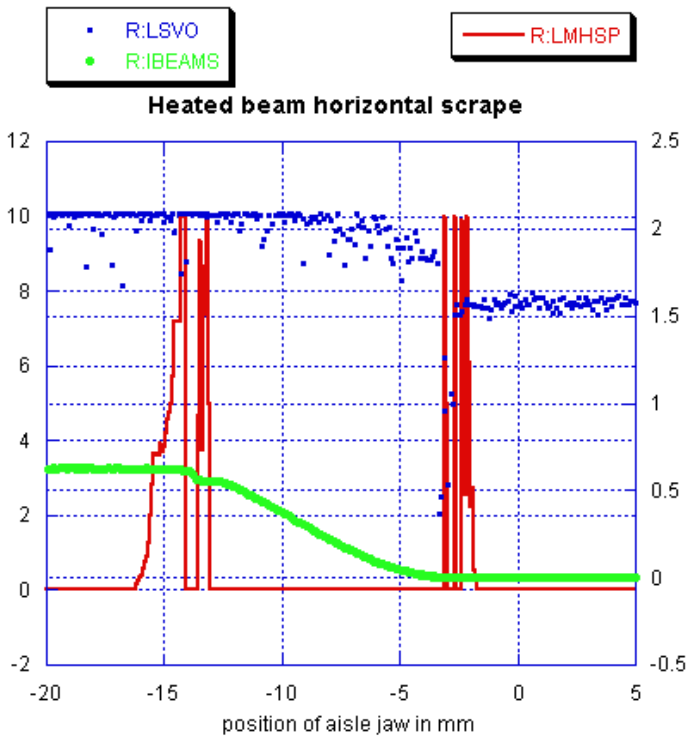

Figure 2: Horizontal admittance measurement.

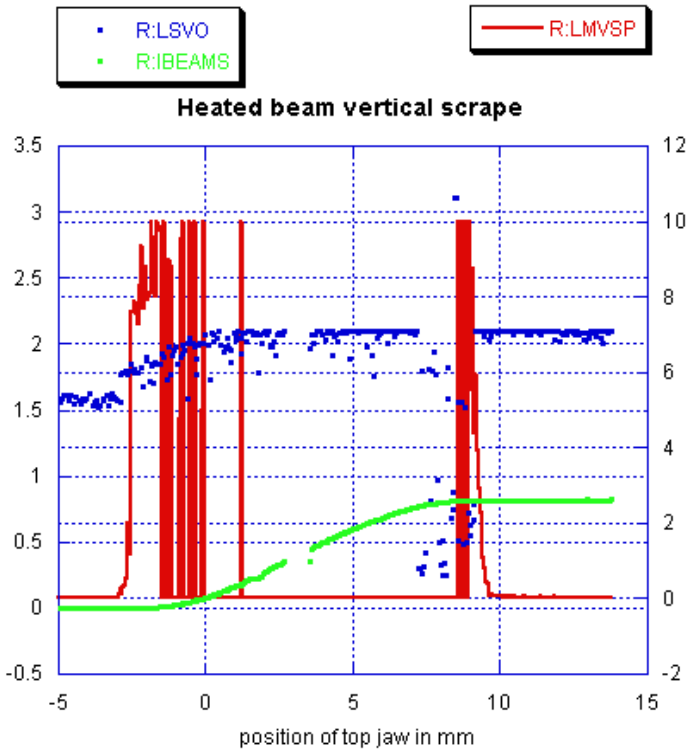

Figure 3: Vertical admittance measurement