TRANSVERSE EMITTANCE MEASUREMENTS IN MEBT AT SNS

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Abstract

The latest modifications of the Medium Energy Beam Transport (MEBT) emittance scanner and the test results are presented. The scanner consists of a slit and harp placed in the MEBT section of Spallation Neutron Source (SNS) Linac with H- energy of 2.5 MeV. It was initially commissioned during the early days of SNS. The initial design allowed to get information about beam core but was incapable of getting precise data about halo. Several improvements in hardware and software were performed recently. They significantly increased signal to noise ratio, reduced harp wires electron coupling and increased scan speed. The latest measurements with the new system show a good agreement with the simulation results from simple models.

EMITTANCE SCANNER

The emittance scanner is a classical slit-harp device with carbon slit and tungsten wires. The list of device parameters is shown in Table 1. Horizontal and vertical slit are placed in the same location along beam line so both profiles are taken at the same longitudinal coordinate. The both harps are placed 353 mm downstream from the slits. In order to protect the slit beam is limited by 50 uS of macro pulse length and 2 Hz repetition rate. Collision detection system avoids inserting two harps (or slits simultaneously).

Table 1: Scanner and Beam Parameters

Parameter	Value
Ion Energy (H^-)	2.5 MeV
β = v/c	0.073
Slit – harp distance	353 mm
Signal wires	16
Distance between wires	1 mm
HV Bias	+300 V
Macro pulse length	~ 40 uS
Beam current	~ 30 mA
Slit	0.1 mm carbon
Wire	0.1 mm tungsten

Raw Signals

The electronics detects secondary electron emission from the wires induced by H^- ions being deposited in the wire thus the measured current is positive.

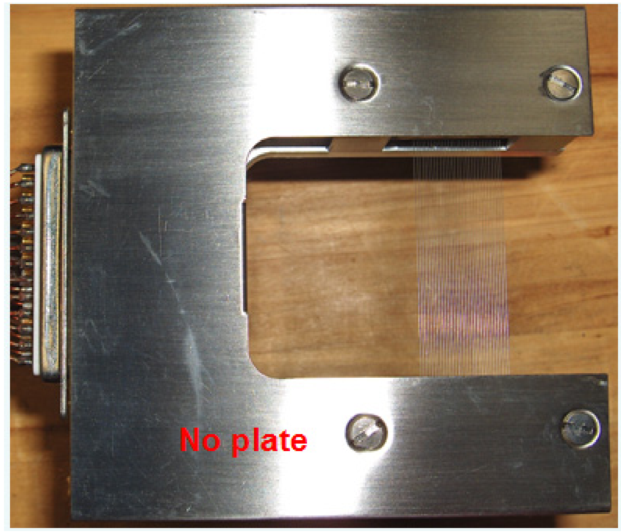

Figure 1: X-harp, bias plate removed.

The Fig. 2 shows typical signals coming from the wires (after being inverted by the amplifier).

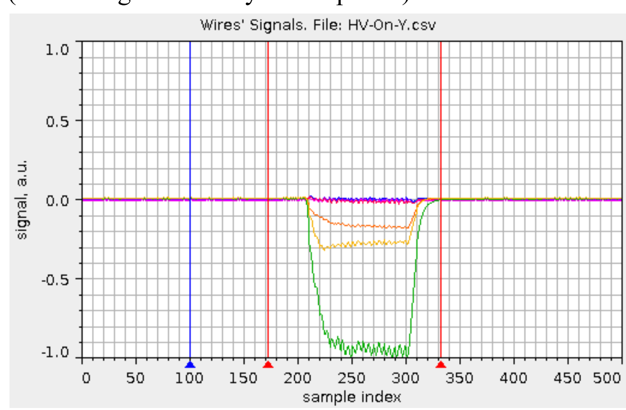

Figure 2: Raw signal from harp with HV = 300V.

After several considerations [1] a simple transimpedance amplifier (Fig. 3) is used and the harp is treated as a current source so the cable connection is single ended at the harp side (no ground connection to the beam line).

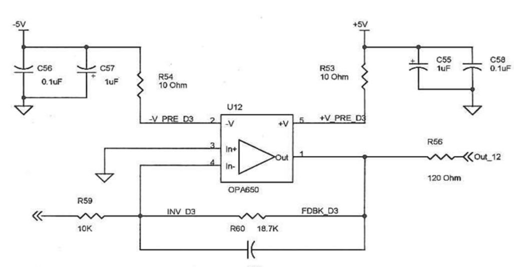

Figure 3: Amplifier schematics.

Signal Coupling

The biggest problem we encountered is signal coupling between wires. The coupling has two completely different natures.

The electron coupling originates from the fact that electrons emitted from the wire travel to another wire and are absorbed by it. So the nearby wires have an induced signal of opposite polarity (Fig. 4).

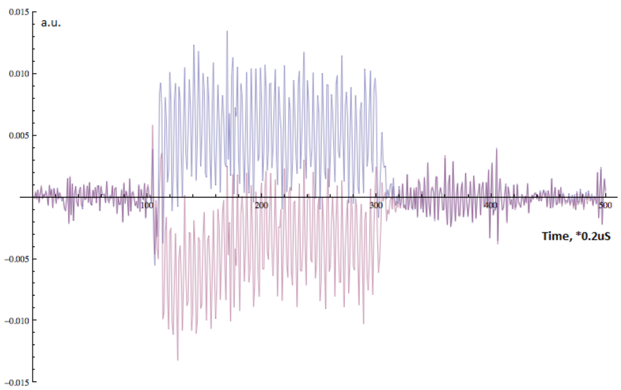

Figure 4: Electron coupling. Red waveform shows the real signal on wire and blue one shows induced signal on the next wire. No bias applied to screening wires.

Initially every harp had a back plate that absorbed the beam passed through the wires. The plate had bias to remove electron coupling but it was not sufficient. We ended up applying bias to every other wire so the signal wires are effectively screened and do not cross talk. In this configuration the plate is no longer needed and actually makes coupling worse so it was removed as shown on Fig. 1.

In addition to electron coupling there is an electrical coupling between cables (and wires).

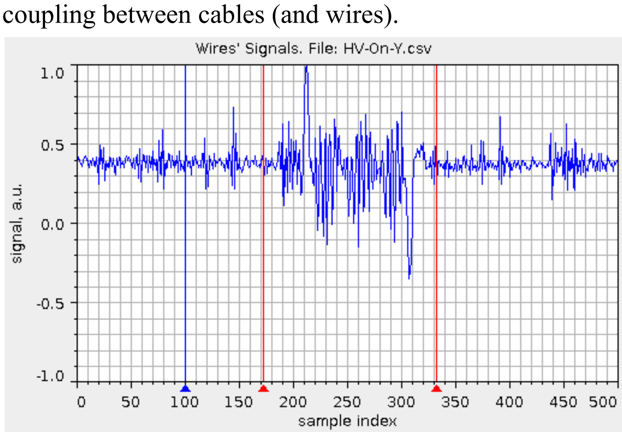

Figure 5: Electrical coupling due to capacitance between wires.

The signal from one wire induces a signal proportional to its derivative on the next wire (Fig. 5 shows induced signal only). This type of coupling can be mitigated by improving cable type and layout. We are investigating if switching to individual coaxial cable per wire will improve the situation compared to currently installed multi wire cable which is a bundle of twisted pairs.

The coupling reduction is very important. The ~5% coupling between wire that is inserted in the centre of the beam and a wire being outside of the beam can easily decrease measured emittance by 30%.

Software

The LabVIEW based software was greatly improved since [2]. The most problematic part was low scan speed. The new version allows scans at 2Hz rate (the limit comes from slit overheating considerations). Simple emittance measurement scans (30 slit steps by 4 harp steps) take one minute. Since SNS facility is in production stage and time allowance for accelerator studies is constantly decreasing, any reduction of time needed for scan is valuable.

MEBT SCRAPER MEASUREMENTS

Easy way of checking emittance measurement device is insertion of some sort of collimator upstream of the device.

We checked our horizontal MEBT scrapers [3] effectiveness with emittance scanner. The results are presented on Fig. 6, 7.

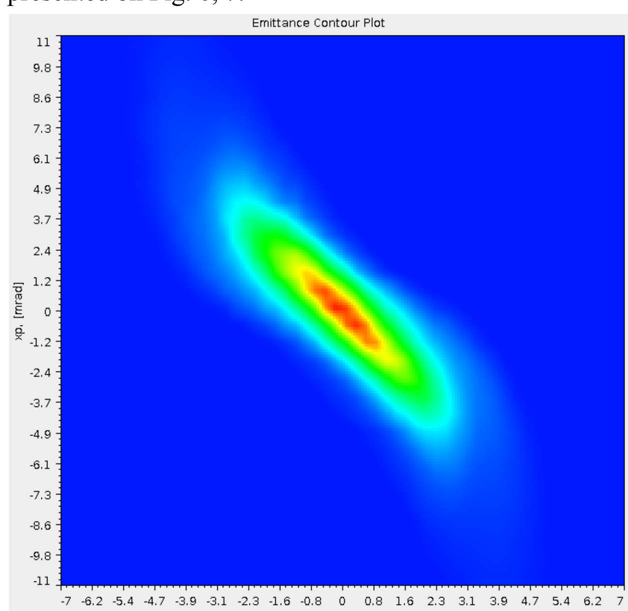

Figure 6: MEBT scrapers retracted. RMS emittance 0.23 mm mrad.

It is clear that the beam has been scraped at one side only. Also we should mention that these results were obtained with old electronics that had coupling problem fixed later. That is why the emittance value is so small (should be around 28-30 mm mrad) but qualitatively the picture gives good idea of scraping effectiveness.

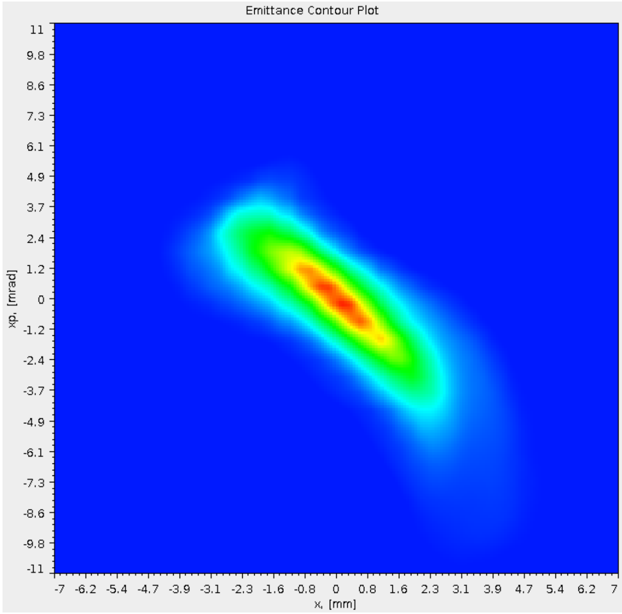

Figure 7: MEBT scrapers inserted. RMS emittance 0.18 mm mrad.

PHASE SCAN MEASUREMENTS

The improved scanning time allowed to make series of emittance measurements vs rebuncher phase. The MEBT rebuncher is located 22 cm upstream of the emittance scanner.

We considered simple thin lens model for the rebuncher that gives following transformation in RF gap [4]. The index 0 corresponds to values before the gap and 1 to values after the gap.

$$\begin{cases} x_1 = x_0 \\ x_1' = \eta(\phi_{rf}) \cdot x' + \kappa \cdot x_0 \cdot \sin(\phi_{rf}) \end{cases}$$

$$\kappa = -\frac{\pi \cdot |q| \cdot E_0 T L_{rf}}{m \cdot c^2 \cdot \beta^3 \cdot \gamma^3 \cdot \lambda}$$

$$\eta(\phi_{rf}) = (\beta \cdot \gamma)_0 / (\beta \cdot \gamma)_1 \cong (1 - \frac{1}{2} \cdot \frac{E_0 T L_{rf}}{E_{ini}} \cdot \cos(\phi_{rf}))$$

Performing averaging over beam ensemble:

$$\overline{(x'_1)^2} = \overline{\eta^2} \cdot \overline{(x_0')^2} - \left(\overline{2\eta \cdot \sin(\phi_{rf})}\right) \cdot k \cdot \overline{x_0' x_0}$$
$$+ k^2 \cdot \overline{x_0^2} \cdot \overline{(\sin(\phi_{rf}))^2}$$

The interesting property of these equations is the last quadratic term. Its significance depends on initial condition (emittance before the gap). Figure 8-9 show the model prediction and measurements for two different beam conditions and the curve shape is quite different.

SUMMARY

MEBT emittance scanner is a fully functional device and the measurements are within good agreement with simple model. Future improvements will include further coupling reduction and bandwidth increase.

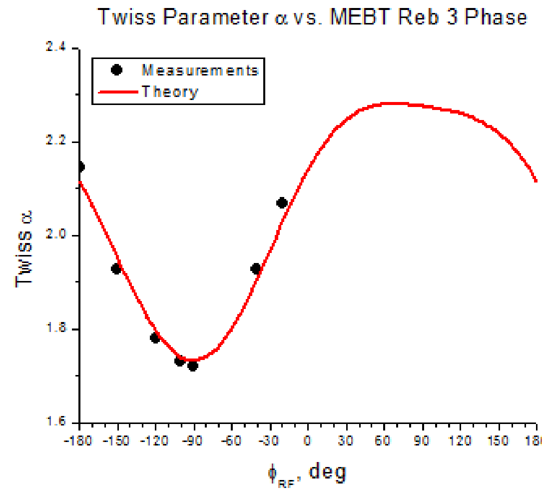

Figure 8: Twiss parameters vs rebuncher's phase.

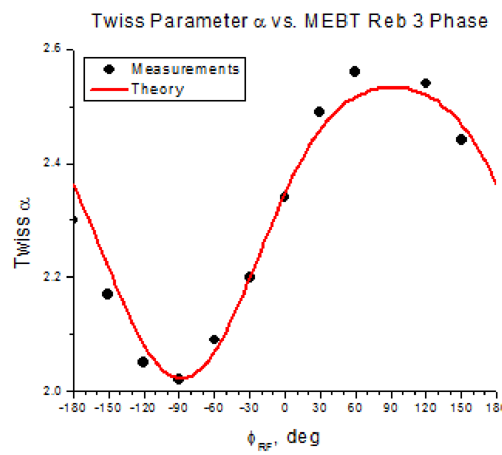

Figure 9: Twiss parameters vs rebuncher's phase.

ACKNOWLEDGEMENTS

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