# TIME RESOLVED EMITTANCE MEASUREMENT IN THE UNIVERSITY OF MARYLAND ELECTRON RING*

M. Walter#, D. Lamb, S. Bernal, I. Haber, R. A. Kishek, H. Li, B. Quinn, M. Snowel, A. Valfells, M. Reiser, P.G. O'Shea, Institute for Research in Electronics and Applied Physics, University of Maryland, College Park, MD 20742

## *Abstract*

Initial experimental results are presented for measurements of the emittance of an electron beam in the University of Maryland Electron Ring (UMER). Two independent sets of slit-collector systems are used to measure the emittance in the vertical and horizontal directions respectively. Results are then compared to the time integrated emittance measurements obtained from a pepperpot. The UMER electron beam has an energy of 10 keV, with as much as 100 mA of current, and pulse length of 100 ns. The beam is confined by a periodic lattice of focusing/defocusing quadrupole magnets at 16 cm intervals. Beam steering is achieved with dipole magnets at 32 cm intervals and additional small steering dipoles as needed.

## INTRODUCTION

The University of Maryland Electron Ring (UMER) is a low voltage (10 kV), high intensity (100 mA), recirculating electron ring designed to explore the physics of space charge dominated beams [1,2,3]. Emittance growth caused by a variety of factors, such as injection mismatch, beam steering, focusing, etc., is of keen interest to the entire accelerator community. Our key goal was to develop a method to measure the time resolved beam emittance and be able to map the phase space distribution as a function of time during the beam pulse. When combined with an energy analyser, this system will enable us to plot the full time-dependent, six dimensional, phase space of the beam [4].

## PROCEDURE

Previous attempts to measure beam emittance have been unsuccessful due to tremendous amount of noise pickup from oscillatory modes within the diagnostic chamber. The wire from our previous slit-wire collector has been replaced by a shielded collector bar to reduce the noise in the data collection circuit. The collector bar is isolated from its environment by a conducting box and ceramic insulators. Mounted on the front of the box are adjustable shutter doors. The gap between the shutters may be changed to mimic a change in the wire size of a standard harp-like wire collector. The gap presented in this work was fixed at 0.5 mm. The setup is shown in Figure 1.

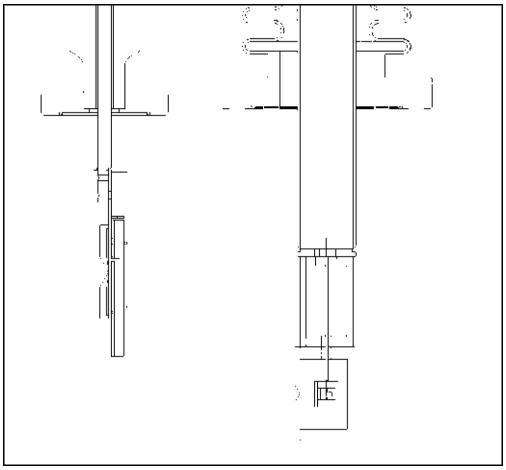

Figure 1: Slit-collector cut away view.

The overall concept of data collection remains the same as in most cases of emittance measurement with a slit-wire system [5,6]. The slit is scanned across the beam in discrete steps. At each step the collector sweeps across the portion of the beam that is not blocked by the slit. Control of the motion of both the slit and collector is achieved by use of stepper motor with position encoders. The stepper motor control and data collection have been automated through an interface with LabView software. A schematic of this setup is shown in Figure 2.

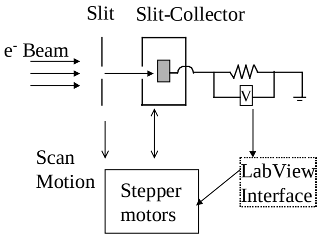

Figure 2: Slit-collector schematic.

## RESULTS

A sample voltage trace for a 25 mA beam is shown in Figure 3. All data presented in this work is for a 25 mA, 10 keV beam. The low current beam was used because of the relative ease of experimental beam envelope matching as compared to the full 100 mA beam. The dotted trace is unfiltered and can be seen to contain an unacceptable amount of noise. The primary source of this noise is the fact that a majority of the beam is intercepted by the slit, which is not isolated from our electrical grounding of the ring. To eliminate this source of noise,

---

*This work is funded by US Dept. of Energy grant numbers DE-FG02-94ER40855 and DE-FG02-92ER54178.
#mwalter@ireap.umd.edu

we simply moved the collector completely out of the beam path and recorded the noise signal for each slit position. The noise may then be subtracted from the signal. This process yields the solid trace in Figure 3.

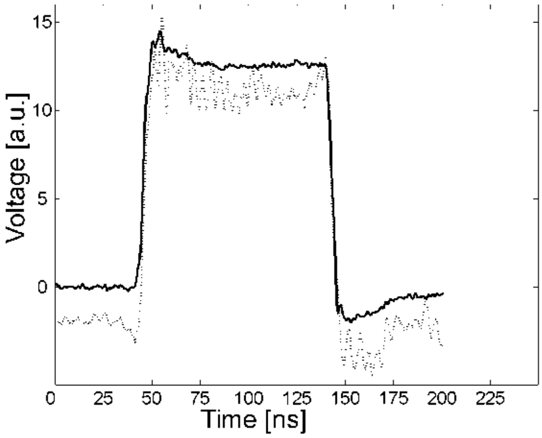

Figure 3: Current signal, raw (dotted line) and with noise subtracted (solid) at $x_{slit}$=2.54 mm and $x_{coll}$=4.41 mm.

Figure 4 shows a complete scan of the collector (X') for a fixed position of the slit ($x_{slit}$=2.54 mm). It can be seen in this figure that dynamics at the head and tail of the beam cause large uncertainty in the measurement. The higher energy head of the beam appears to have shifted toward the center of the ring (increasing x'), while the low energy tail moves to a larger radius.

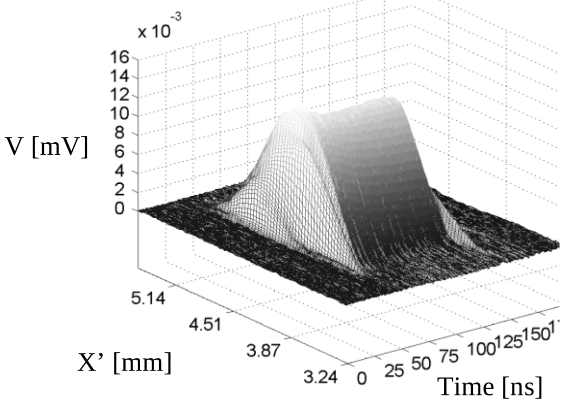

Figure 4: Filtered collector scan (x') for fixed slit position ($x_{slit}$=2.54 cm).

Figure 5 shows a full scan of the collector at $x_{slit}$=7.62 mm. The radial sheer in the beam at this position is obvious. It could possibly be caused by a slight mismatch or misalignment of the beam. As these are only initial measurements, additional investigation is warranted to explain the physical mechanism of the beam dynamics. This plot is shown primarily as a demonstration of the time and special resolution achieved in these initial experiments.

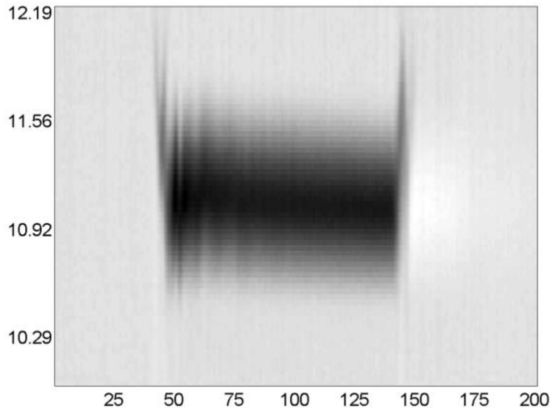

Figure 5: Collector scan for fixed slit position ($x_{slit}$=7.62 cm) showing beam shear.

Figure 6 shows a plot of the time-integrated, transverse phase space, x vs. x' (top) and y vs. y' (bottom). We also have the ability to plot the 4-dimensional velocity space as a function of time. The calculated emittance values for these plots are (presented as 4*$\varepsilon_{rms}$) $\varepsilon_x$=30 µm and $\varepsilon_y$=20 µm. Corresponding measurements under identical beam conditions with a pepperpot yielded values of 42 µm and 28 µm. Differences between the pepperpot and slit-collector may be due to a few systematic errors. The bounds of integration for the slit-collector method were fixed to avoid the head and tail of the beam, where a large contribution to the time integrated emittance may exist. Inaccuracies may also result in the pepperpot measurements because of the relatively low current beam used and resultant small spot size available for photo processing.

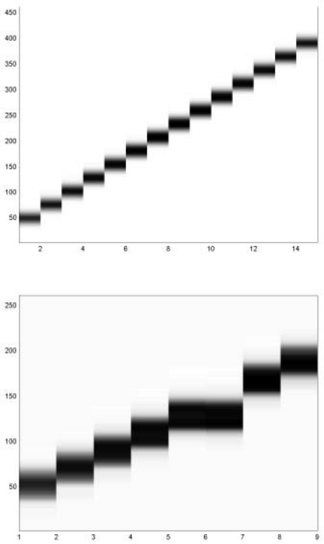

Figure 6: Time integrated phase space plot of x' vs. x (top) and y' vs. y (bottom).

## CONCLUSIONS

An automated emittance measurement system has been built and successfully tested on UMER. It is fully capable of mapping time resolved transverse phase space with a resolution of 2 ns. An initial comparison of time integrated emittance measurements with those of the pepperpot give $\varepsilon_x$=30 µm and $\varepsilon_y$=20 µm for the slit-collector, and $\varepsilon_x$=42 µm and $\varepsilon_y$=28 µm from the pepperpot.

It should be noted that these are only initial results. Experiments with time-resolved measurements of the full beam have begun. Future plans include a feedback loop to modify beam steering and focusing in order to minimize emittance.

## REFERENCES

[1] http://www.ireap.umd.edu
[2] P. O'Shea, et. al., "Experiments with space-charge-dominated beams for heavy ion fusion applications", Laser and Particle Beams (2002), 20, 599-602.
[3] S. Bernal, et. al., "Beam Transport Experiments over a Single Turn at the University of Maryland Electron Ring", these proceedings.
[4] Y. Zou, et. al., "Space-Charge Effects in Retarding Field Energy Analyser", these proceedings.
[5] D. Engwall, "High brightness Electron Beams from a DC, High-Voltage, GaAs Photoemission Gun", PhD dissertation, Univ. of IL at Urbana-Champaign, 1988.
[6] M. Zhang, "Emittance Formula for Slits and Pepper-pot Measurements", FermiLab-TM-1988, Oct. 1996.