PERFORMANCE OF WIRE SCANNER BEAM PROFILE MONITORS TO DETERMINE THE EMITTANCE AND POSITION OF HIGH POWER CW ELECTRON BEAMS OF THE NBS-LOS ALAMOS RACETRACK MICROTRON*

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Introduction

The NBS-LANL Race Track Microtron (RTM) injector produces a sub-millimeter diameter, 600 μA, 5 MeV CW electron beam. In order to steer and focus this electron beam and to measure its emittance and energy spread, a system of wire scanner beam profile monitors has been developed. As shown in Figure 1, three wire scanners are mounted in a straight line with approximately one meter spacing for emittance measurements. The fourth wire scanner is positioned after a 45° bending magnet for energy spread measurements.

Wire Scanners

The wire scanners[1], shown schematically in Figure 2, consist of 30 μm diameter carbon wires mounted in an "L" pattern on insulated standoffs on an aluminum frame as in Figure 3. The wires are moved through the electron beam ten times per second by a pneumatic cylinder. An electroformed metal bellows is used as a vacuum seal. The wire scanners are mounted on the beam line at a 45° angle from vertical so the first wire (vertical) of the "L" measures the horizontal beam current distribution while the second wire (horizontal) measures the vertical distribution on each sweep. Secondary emission current produced by the high energy electrons passing through the wires (approximately 3 % of intercepted electron beam current) is output through an electrical feed-through. The position of the wires is measured by a precision linear resistor with 25 μm accuracy. All components have been tested for a 2 x 10^8 cycle lifetime. A wire scanner is shown in Figure 4.

The secondary emission current is routed to an amplifier via an ultra flexible low noise cable. The amplifier is an ultra low noise current-to-voltage amplifier with remotely switchable gain. The output of this amplifier is connected to the "Y" channel of an X-Y oscilloscope. The position signal from the linear resistor is connected to the "X" channel of the X-Y oscilloscope. Figure 5 is a photograph of a typical oscilloscope output for a 250 μA, 5 MeV electron beam.

Relativistic electrons lose approximately 2 keV passing through the carbon wires. Due to small angle scattering

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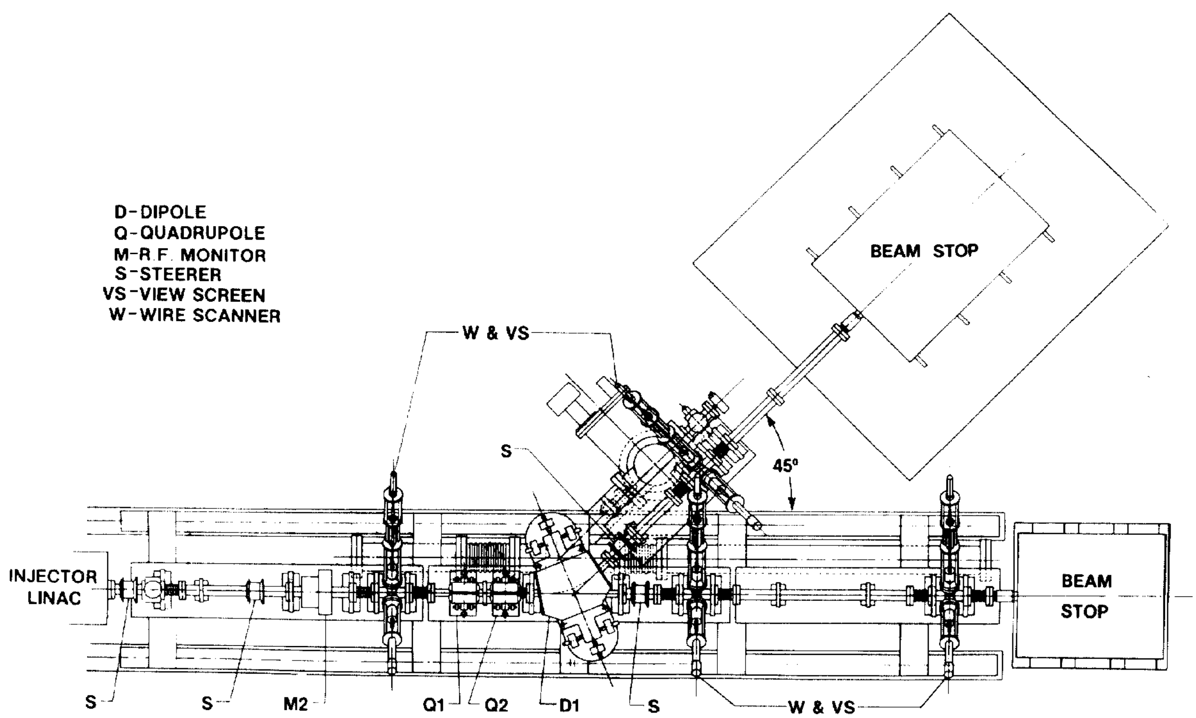

Figure 1. Overhead view of the emittance measuring system for the NBS-LANL RTM 5 Mev injector.

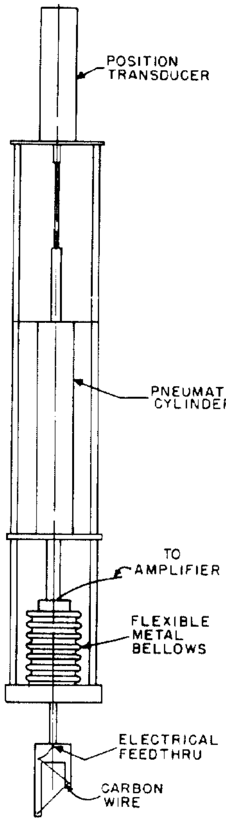

Figure 2. Sketch of a wire scanner.

these electrons are effectively lost from the beam. This loss of beam, time-averaged, is .05 %.

Emittance Measurements

Beam radius measurements were made of 50 to 500 μA CW beams using the three wire scanners mounted in a straight line path. For the purposes of this report, the beam radius is defined as the half width at 20 % of maximum beam peak. For the beam current distributions measured, this encompasses 95 % or more of the total beam current.

Given measurements of beam radii in three locations with known separations, one can solve for beam emittance, ϵ, using the following equations of motion for a beam drifting in a field-free region:

$$X_n^2 = X_0^2 + \theta^2 (L_n - S)^2$$

for n = 1, 2, 3

$$\varepsilon = X_0\theta$$

Where X_n is the beam radius at location n

L_n is the distance from the origin to location n

X_0 is the radius at the beam waist

θ is the beam divergence at the waist

S is the distance from the origin to the beam waist

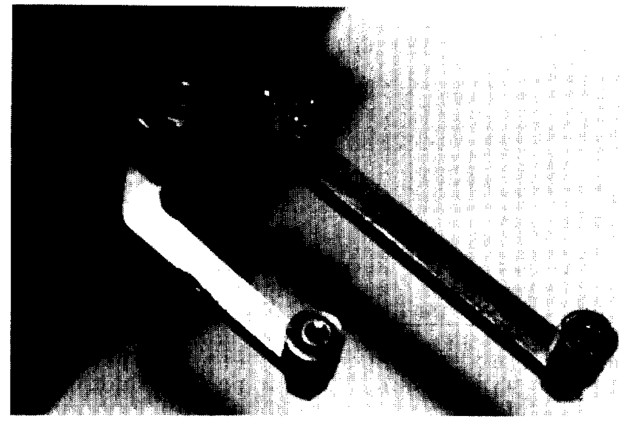

Figure 3. Photograph of 30 μm carbon wires mounted on insulated standoffs on wire scanner. Note that standoffs are shielded to prevent charging by scattered electrons.

The best accuracy is obtained when the waist is at or near the middle wire scanner. This produces the greatest variation in the three measured radii and the smallest sensitivity to measurement errors. Beam radii measured were between 0.1 and 0.6 mm with 0.05 mm resolution. The smallest measurement of beam emittance with the wire scanners in the present configuration was 0.03 mm·mr (+/- 10 %).

Energy Measurements

Energy measurements were made with a wire scanner located 0.54 m from a 45° bending magnet. The momentum dispersion at this point was 4.8 mm / %. The wire scanner was therefore easily able to resolve the minimum observed energy width (at 20 % of maximum beam height) of 5 keV (+/- 10 %).

References

1. R.I. Cutler, D.L. Mohr, J.K. Whittaker, and N.R. Yoder, A High Resolution Wire Scanner Beam Profile Monitor with a Microprocessor Data Acquisition System, IEEE Trans. Nucl. Sci. NS-30, p. 2213 (1983).

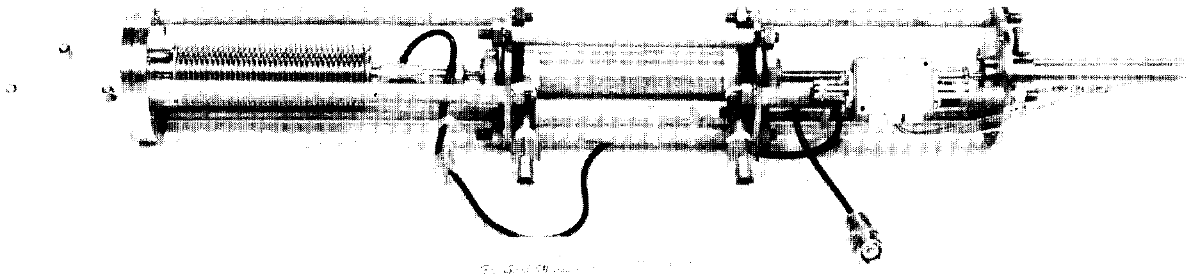

Figure 4. Photograph of wire scanner.

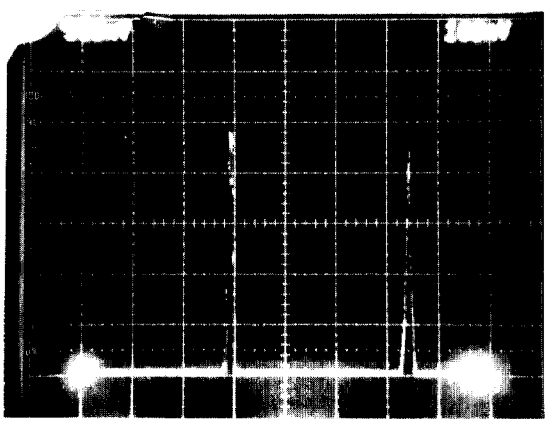

Figure 5. Photograph of wire scanner output to oscilloscope. Horizontal axis is position (3.5 mm/div.), and vertical axis is current. The two peaks correspond to the X and Y beam profiles of a 250 μA 5 MeV CW electron beam.