NIST-Los Alamos Racetrack Microtron Status

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Introduction

The NIST-Los Alamos Racetrack Microtron (RTM) is designed to deliver a low-emittance electron beam of up to 0.5 mA cw over an energy range of 17 MeV to 185 MeV. Fed by a 5 MeV injector, the RTM contains two 180° end magnets that recirculate the beam up to 15 times through a 12 MeV RF linac. The linac, which operates in a standing-wave mode at 2380 MHz, has been tested to nearly full RF power. At present, the injector has undergone beam tests,[1] and the beam transport system is complete through the 12 MeV linac. A temporary beam line has been installed at the exit of one end magnet to measure the beam energy, energy spread, and emittance after one pass through the accelerator. Preliminary results indicate that the accelerated beam energy spread and emittance are within design goals.

Accelerator Description

The RTM and injector, shown in Figure 1, are connected by a 180° achromatic beam transport system (shown in Figure 2), which injects the 5 MeV beam onto the RTM accelerator axis. The two end magnets recirculate the beam through the 12 MeV linac up to 15 times by way of separated return lines. A single, 500 kW, cw klystron delivers RF power to four separate accelerating sections (two on the injector and two on the RTM axis) by way of a waveguide RF distribution system. The phase and amplitude of each linac section are independently controlled. Tests of the RF system[2] have confirmed that phase and amplitude stability are well within design requirements.

To measure the effect on the electron beam of the first-pass acceleration through the RTM linac, a temporary beam line has been installed in place of the return lines at the exit of end magnet E1, parallel to the linac axis at a displacement of 66 cm. This configuration is shown in Figures 3 and 4. Included on this one-pass return beam line are three viewscreens, spaced three meters apart, to determine the beam position, shape, and approximate size. A wirescanner assembly[3] is included near each viewscreen for more precise measurements of the beam size. A Hall probe, calibrated by an adjacent NMR, is used to measure the end magnet field.

Beam Transport, Acceleration, and Measurement

Conditions calculated to provide achromatic beam transport have been verified experimentally for each 90° section of the 180° transport beam line between the 5 MeV injector and the RTM. The final dipole magnet in the transport system deflects the 5 MeV beam through an angle of 15° onto the RTM accelerator axis. Three low-field steering magnets (S16-S18, Figure 4), one located at each end of the linac and one between the two linac sections, are used to keep the beam on the accelerator axis over the 12.5-meter distance between end magnets. Quadrupole doublets ($Q_{6,7}$ and $Q_{8,9}$, Figure 4) are located at each end of the RTM linac.

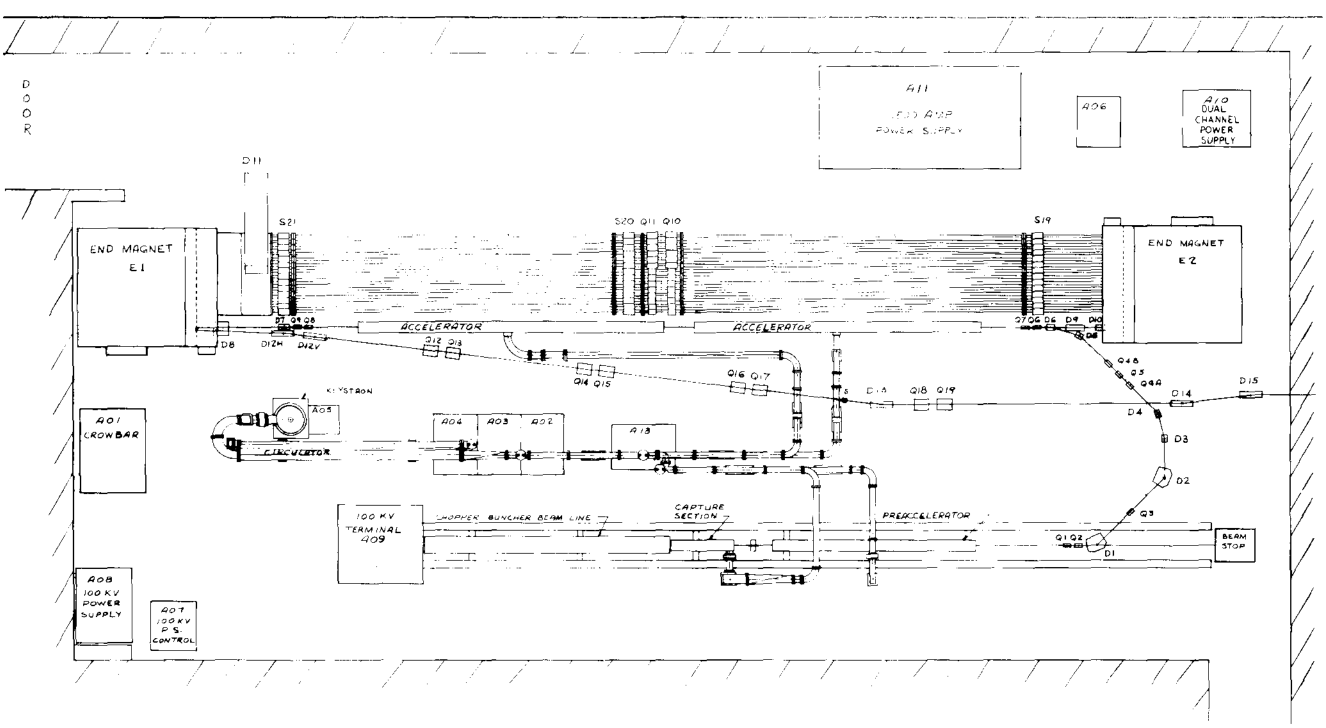

Figure 1. Plan view of the completed RTM.

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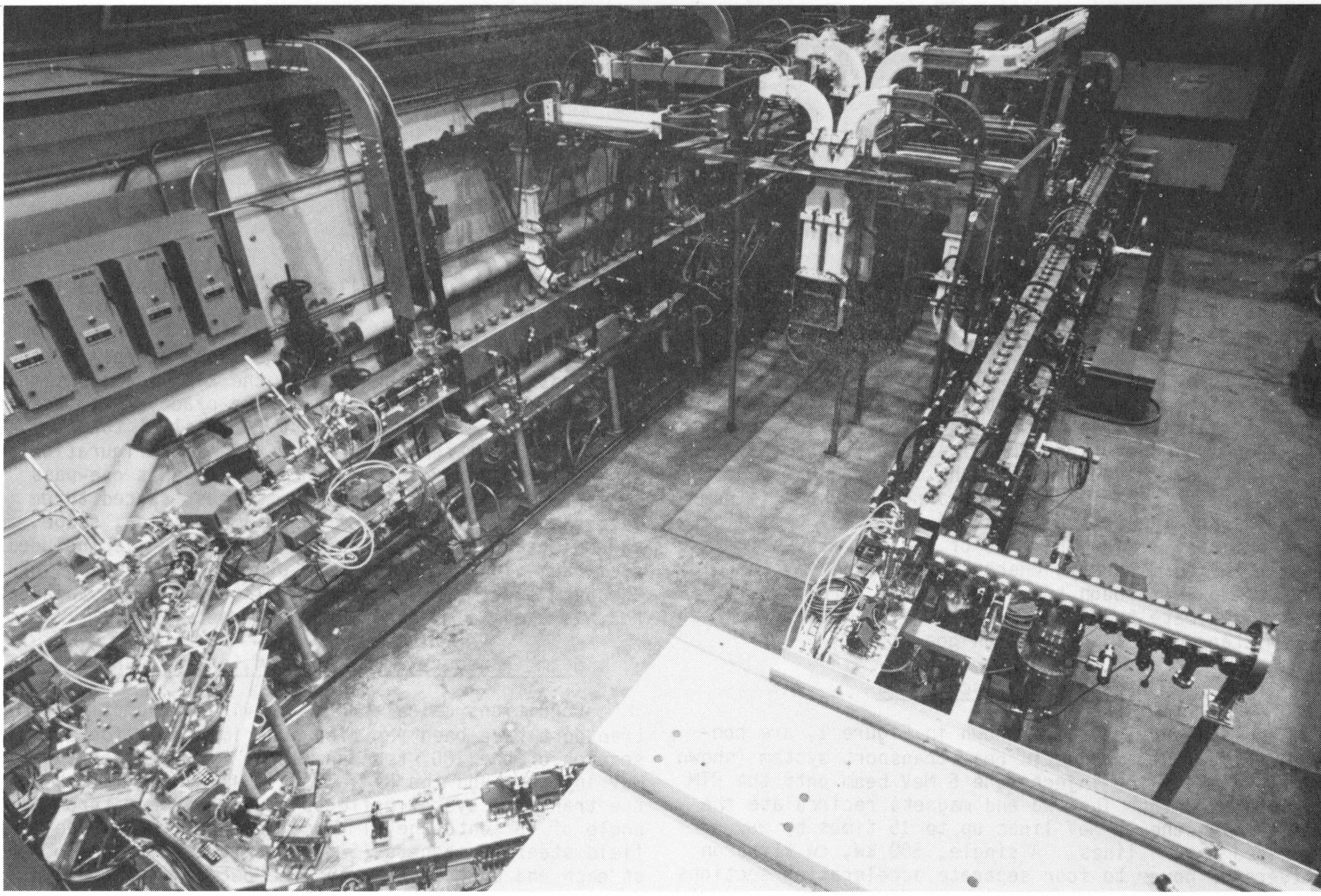


Figure 2. View of the RTM from the top of end magnet E2, prior to completion of the one-pass return line. The 180° beam transport line, with the magnetic shields removed, is to the left and bottom in the picture.

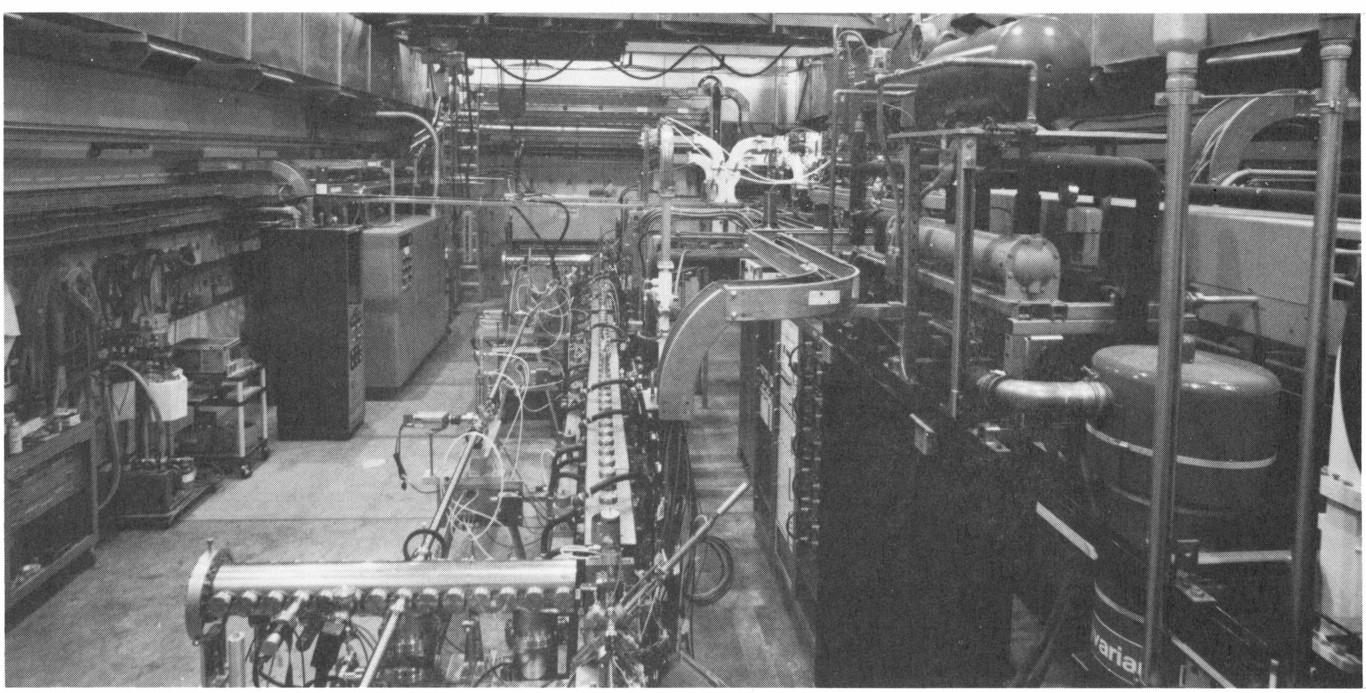


Figure 3. View of the RTM from the top of end magnet E1, showing the one-pass return beam line to the left of the RTM accelerator axis.

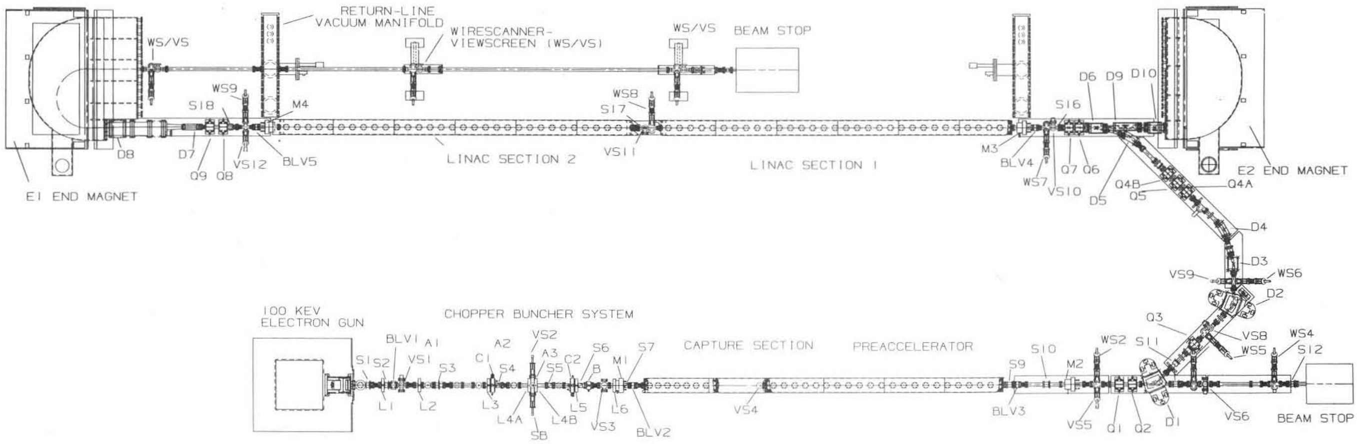
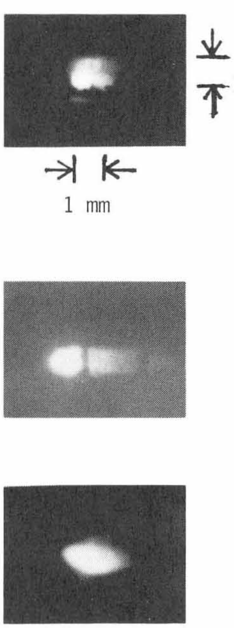


Figure 4. Plan view of the RTM with the one-pass return line.

The 5 MeV beam was aligned on the RTM accelerator axis and deflected by end magnet E1 onto the one-pass return beam line. The RF power in the first linac section was raised to about 100 kW, and the accelerator RF phase was adjusted to maximize the beam energy gain, as determined by the magnetic field in E1. This sequence was repeated with the second linac section. The maximum beam energy attained with power in both accelerators was 16.2 MeV, limited during these preliminary beam tests by the voltage gradient sustainable in the second linac. This limit will be overcome as linac conditioning continues.

The power in the accelerating sections was reduced by about 10% for the sustained operation required to carry out the beam tests. Figure 5 shows the accelerated beam spot produced on viewscreens along the one-pass return beam line axis. The beam is about 1 mm high (y) by 2 mm wide (x). With no steering applied beyond the middle of the linac to the end of the one-pass return line, the beam passed within 1 mm of the center of each viewscreen, indicating good alignment of the beam with both the accelerating fields and magnetic guide fields.

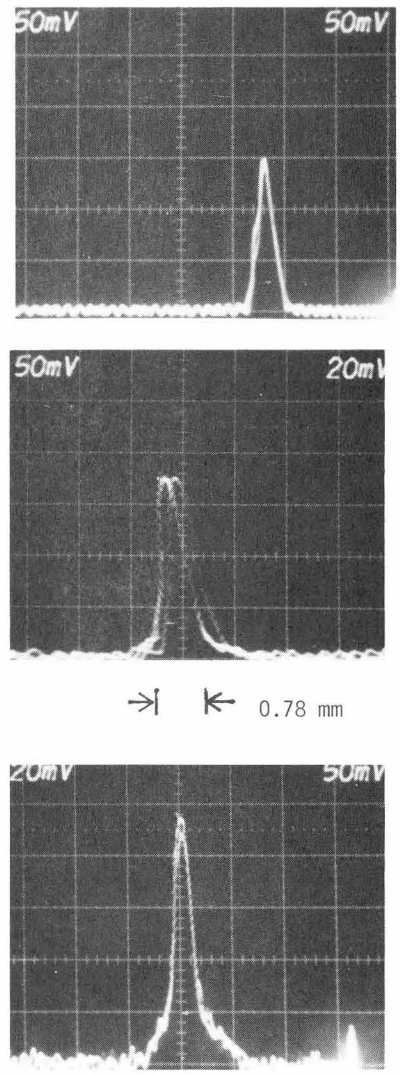


(a)

(b)

(c)

Figure 5. Image of accelerated beam on viewscreens located three meters apart on one-pass return line axis. a) 1 m from E1 exit, b) 3 m from (a), c) 6 m from (a).



(a)

(b)

(c)

Figure 6. Oscilloscope traces of the signal produced as the y-scanning wires pass through the accelerated beam on the one-pass return line.
a) Beam y-profile about one meter from the exit of end magnet E1.
b) Beam y-profile 3 m from (a). The horizontal scale is magnified 2.5x relative to (a) and (c).
c) Beam y-profile 6 m from (a).

The quadrupole doublet, Q_8 and Q_9, located at the exit end of the RTM Linac (Figure 4), was adjusted to produce a waist in the y-direction near the middle of the one-pass return beam line to facilitate emittance measurements with the three wirescanners. Figure 6 shows the beam profile in the y-direction as measured by these wirescanners. The focusing produced a 0.8 mm vertical beam waist near the middle wirescanner. Following a technique described in an earlier paper,[1] the normalized transverse y-plane emittance[4] was determined from these beam size measurements to be 2.35 μm. The x-plane emittance was not determinable, from similar measurements, due to energy spread effects. Beam envelope measurements along the accelerator axis will be included during further planned beam tests, in order measure the x-plane emittance and the beam energy spread independently.

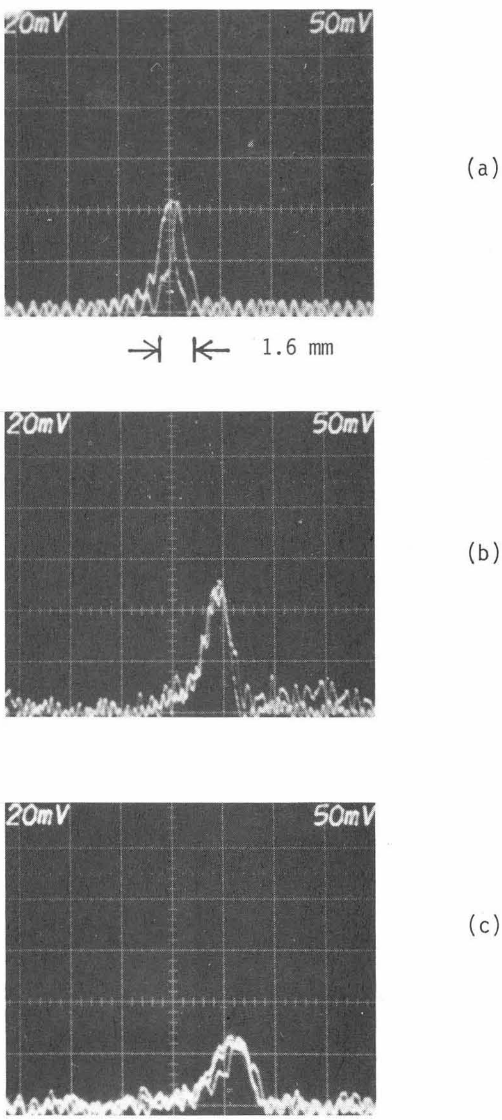


Figure 7. Oscilloscope traces of the signal produced as the x-scanning wires pass through the accelerated beam on the one-pass return line.
a) Beam x-profile about one meter from exit of end magnet E1.
b) Beam x-profile 3 m from (a).
c) Beam x-profile 6 m from (a).
The beam was focused to a waist near (a) by the quadrupole doublet, Q_8 and Q_9.

As a first estimate of the accelerated beam energy spread, the beam was focused to as small a size as possible in the x-direction near the first wirescanner on the one-pass return beam line by the quadrupole doublet, Q_8 and Q_9. Figure 7 shows the beam profiles at the three wirescanner positions along the one-pass beam return line under these conditions. The minimum beam envelope width was measured to be about 1.6 mm. From the minimum y-waist measured from the data in Figure 6, and assuming equal x- and y-emittance for the accelerated beam, the emittance part is estimated to contribute a little more than 1/2 to the beam envelope size. Therefore the momentum dispersion contribution to the beam size is estimated to be 0.7-0.9 mm, corresponding to a full energy spread of 16-20 keV.

Summary and Conclusions

Preliminary measurements of the electron beam after one acceleration through the RTM linac have been made. The maximum energy achieved thus far is 16.2 MeV. The measured normalized emittance after one pass is 2.35 μm and the estimated energy spread is 16-20 keV. The design goals for normalized emittance and energy spread at 185 MeV are 5 μm and 36 keV, respectively. The energy spread is not expected to increase significantly with multiple passes through the microtron because of phase focusing.

These tests were conducted with a 0.3 mA pulsed beam, with no indication of beam loss. It is evident from these preliminary results that the electron beam can be transported and accelerated through the RTM while beam quality is maintained well within design limits.

Additional one-pass beam tests are planned to include full voltage conditioning of the RTM linac sections, comprehensive beam envelope measurements to determine the x-emittance and for a more accurate energy spread determination, and the transport and acceleration of cw beams up to 0.55 mA average current.

References

1. M.A. Wilson, et al, "Performance of the 5 MeV Injector for the NBS-Los Alamos Racetrack Microtron," Proc. 1987 IEEE Particle Accelerator Conference, 322, December 1987.

2. R.I. Cutler and L.M. Young, "Performance of the High Power RF System for the NIST-Los Alamos Racetrack Microtron," this conference.

3. R.I. Cutler, et al, "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," Proc. 1987 IEEE Particle Accelerator Conference, 625, December 1987.

4. For definition of emittance, see: S. Penner, "RF Linac Based Free Electron Lasers," Proc. 1987 IEEE Particle Accelerator Conference, 185, December 1987.