70 MEV ELECTRON RACETRACK MICROTRON COMMISSIONING

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Abstract

We have designed, built, and begun commissioning our compact 70 MeV Race-Track Microtron (RTM), which includes Rare-Earth Permanent Magnet dipoles, a narrow rectangular accelerating structure with Radio-Frequency Quadrupole focusing, and a pre-bunched electron gun beam injected through a compact fixed-gradient REPM α-magnet. Here we reprise the accelerator design and present commissioning results to date.

1 INTRODUCTION

Figure 1: 70 MeV electron RTM.

Our 70 MeV RTM [1], seen in Fig. 1, diagrammed in Fig. 2, and whose parameters are given in Table 1, consists of injector, accelerating, bending, focusing, extraction, RF, cooling, vacuum, and control systems. Low-energy gun (1) electrons are longitudinally compressed by a pre-buncher (2) and injected into the accelerating structure (3) through an α-magnet (4) [2] and focusing lenses (5). The electrons are then bent through 180º by the first end magnet (6) and, after traversing a drift space, are again retro-directed by the second end magnet (7) that returns them on-axis to the structure. Obtaining external beams from any orbit other than the 1st requires exciting an extraction magnet (8).

2 RTM DESCRIPTION

We previously reported high-power injection (electron gun and α-magnet) and acceleration (Rectangular Cavity Biperiodic Structure [3}) system test results [4], so here we reiterate their principal parameters in Table 2. A compact high-voltage modulator is now being installed to power our new 6 MW multi-beam klystron that produces 16 μs pulses at up to 250 Hz.

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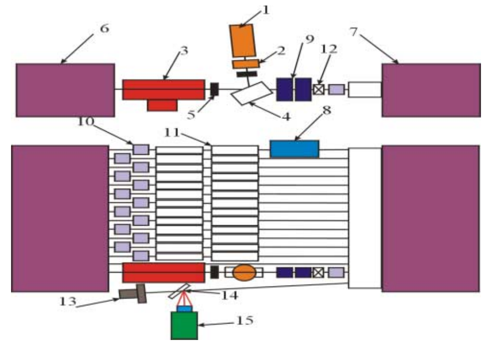

Figure 2: RTM: elevation (bottom) and plan (top) views.

Table 1: RTM parameters.

Characteristic	Value
Injection energy	50 keV
Energy gain/orbit	5 MeV
Number of orbits	14
Output energy	10-70 MeV
Output current at 70 MeV	40 mA
Circumference increase/orbit	1 λ
Operating frequency	2,856 MHz
Klystron power pulsed	6 MW
End magnet field	1.0 T
Dimensions	2.2×1.8×0.9 m^3
Weight	3,200 kg

Table 2: Injection and acceleration system parameters.

Characteristic	Value
Injection energy	50 keV
Injection beam current	200 mA
Maximum output beam current	100 mA
Maximum output beam energy	6.0 MeV
Horizontal/vertical emittance	1/0.7 mm×mrad

The REPM dipole magnets [5] recirculate and vertically focus the RTM beams. Our 0.96 T field is ~4% less than the design value due to inadequacies introduced by the manufacturer, so the orbital energy gain is now 4.8 MeV and the 14th orbit beam energy is 67.4 MeV.

Special ceramic insertions inside stainless steel beam pipes on each straight orbit section contain Beam Current Monitors (10), which are differentially amplified fast current transformers with 4.9 V/A sensitivity. We use a Faraday cup (13) to measure the extracted beam current. We view the beam spot with an intercepting luminescent screen (14) whose transition radiation is reflected onto a shielded CCD camera (15).

The closed-loop cooling system can extract ~15 kW of heat and maintains the RCBS and pre-buncher

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temperature constant to within ~0.1 °C. The vacuum system, which allows one end magnet to move during RTM tuning, achieves its ~10^{-7} mm Hg vacuum with rotary and ion pumps. The control system [6] provides programmed steering coil (11), extraction magnet (8), and quadrupole lens (12) current control; monitors the dissipated RF power and vacuum conditions; and provides remote positioning of the RF system stepping motors.

3 RTM OPTICS

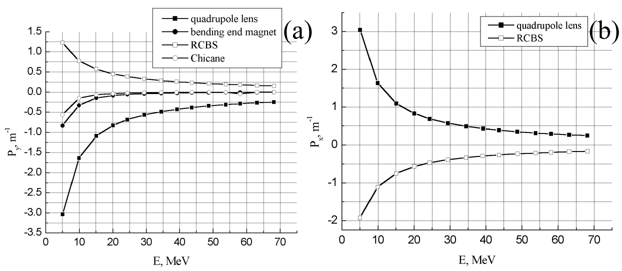

Figure 3: Forces with beam energy:
(a) horizontal and (b) vertical.

The RCBS focuses horizontally and defocuses vertically and so requires a vertical focusing quadrupole lens (8). The optical properties of this lens, the bending magnets, and the RCBS are seen in Fig. 3. The calculated vertical and horizontal particle trajectory displacements from the RCBS entrance axis and the phase portraits of 14th orbit beam are seen in Fig. 4.

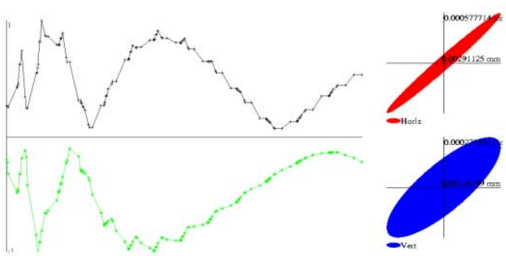

Figure 4: 14th orbit displacement and phase:
horizontal (top) and vertical (bottom).

To decrease the transverse oscillation amplitude quadrupole triplets were installed on 4th, 6th, 8th, 10th and 12th orbits whose focal lengths are 2 m vertically and infinity horizontally. Fig. 5 shows the 14th orbit beam envelope and phase.

4 RTM TUNING

We capture 30% of the 50 keV gun beam into 1st orbit acceleration with the 1.9 MW RCBS pulse power corresponding to a 24º reference phase and the 4.8 MeV synchronous energy gain. The RCBS exit beam energy can only vary by 120 keV since the 1st orbit must be within 2 mm of the axis.

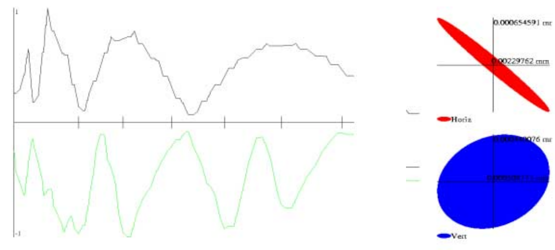

Figure 5: 14th orbit displacement and phase with triplets: horizontal (top) and vertical (bottom).

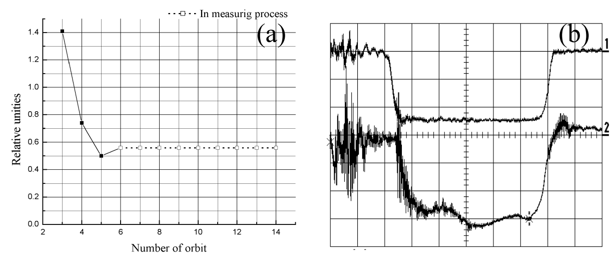

Figure 6: (a) Orbital capture efficiency and
(b) RCBS (top) and BCM (bottom) RF power signals.

Starting with the 3rd orbit, we extract the beam into the Faraday cup and measure the capture efficiency seen in Fig. 6(a). Our Faraday cup was small because we had little space to install it and so most of high-energy electron showers escapes. We calibrated the Faraday cup current using a BCM signal on the 3rd orbit, seen in Fig. 6(b), but this calibration is beam energy dependent.

The 14th orbit capture efficiency depends on the distance between the two end magnets, seen in Fig. 7(a), which in turn depends on the quadrupole lens current, seen in Fig. 7(b). A 14th orbit beam spot is seen in Fig. 8.

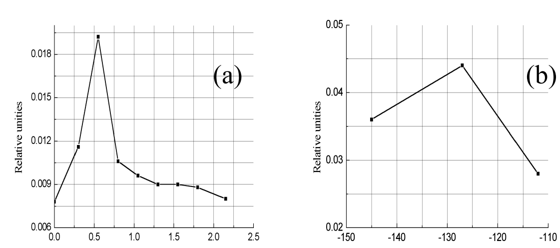

Figure 7: 14th orbit capture efficiency with (a) distance between end magnets and (b) quadrupole lens current.

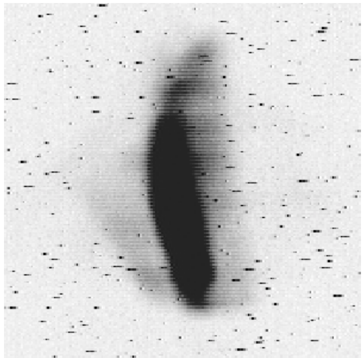

Figure 8: 14th orbit beam image.

5 CONCLUSION

We have designed, built, and begun commissioning our 67.4 MeV electron RTM prototype whose performance we continue to improve. However, our most important improvements will come in the pulse stability with the installation of our new long-pulse modulator and the increased focusing strengths from new compact triplets on each orbit.

6 REFERENCES

[1] V.I. Shvedunov, A.I. Karev, V.N. Melekhin, N.P. Sobenin, and W.P. Trower, "Improved Design of the

[2] Mobile 70 Mev Race-Track Microtron," in Proc. 1995 Particle Accelerator Conf., L. Gennary, ed. (IEEE, Piscataway, 1996) v.2, p.807.

[3] V.S. Skachkov, A.N. Ermakov, and V.I. Shvedunov, "A Fixed Gradient Rare Earth Permanent α-Magnet," in Proc. 2000 European Particle Accelerator Conf., J.L. Laclare, W. Mitaroff, Ch. Petit-Jean-Genaz, J. Poole, and M. Regler, eds. (World Scientific, Singapore, 2000) p.2125.

[4] D.V. Kostin, V.I. Shvedunov, N.P. Sobenin, and W.P. Trower, "A Novel Racetrack Microtron Structure," in Proc. 1999 Particle Accelerator Conf., A. Luccio and W. MacKay, eds. (IEEE, New York, 1999) v.2, p.910.

[5] V.I. Shvedunov, A.N. Ermakov, D.I. Ermakov, F.N. Nedeoglo, G.A. Novikov, N.P. Sobenin, and W.P. Trower, "Rectangular Accelerating-Focusing Structure High Power Tests", in Proc. 2000 European Particle Accelerator Conf., J.L. Laclare, W. Mitaroff, Ch. Petit-Jean-Genaz, J. Poole, and M. Regler, eds. (World Scientific, Singapore, 2000) p.2125.

[6] G.A Novikov, N.I. Pakhomov V.S. Skachkov, V.I. Shvedunov, and W.P. Trower, "Large Permanent Magnet Dipole Performance," these Proceedings.

[7] I.V. Gribov, I.V. Shvedunov, V.R. Yalijan, "Racetrack Microtron Control System," these Proceedings.