The University of Maryland Electron Ring (UMER): A Model Recirculator for Intense Beam Physics Research*

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Outline

• Introduction
• From “Zero-Current” to Extreme Space Charge
• Electron Ring Layout and Diagnostics
• Single-Turn Physics
• Conclusions
UMER is designed for *SCALED EXPERIMENTS* using *LOW ENERGY, HIGH CURRENT* electron beams.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>10 keV</td>
</tr>
<tr>
<td>Current</td>
<td>100 mA</td>
</tr>
<tr>
<td>Generalized Perveance</td>
<td>$1.5 \times 10^{-3}$</td>
</tr>
<tr>
<td>Emittance, rms, norm.</td>
<td>2.5 microns</td>
</tr>
<tr>
<td>Tune Depression</td>
<td>&gt;0.12</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>100 ns</td>
</tr>
<tr>
<td>Lap time</td>
<td>197 ns</td>
</tr>
</tbody>
</table>

Generalized Perveance is given by the formula:

$$K = \frac{2I}{I_0 \left( \beta \gamma \right)^3}$$
Some Current and Future Beam Physics Issues in UMER

Transverse Dynamics:
- **Matching**/Injection
- Exotic Focusing Schemes
- Space-Charge Waves
- **Halos**
- L/T Coupling

Longitudinal Dynamics:
- Bunch Capture/Shaping
- Energy Spread
- Space-Charge Waves
- L/T Coupling

Computer Code Benchmarking
UMER enters a new regime of beam physics

\[ \chi = \frac{K}{k_0^2 a^2} \]

Emittance Dominated

Space-charge Dominated

Plasma Oscillations Curve

\[ \frac{\omega_p}{\omega_0} = \sqrt{2\chi} \]

Betatron Oscillations Curve

\[ \frac{\omega}{\omega_0} = \sqrt{1 - \chi} \]

Intensity Parameter (\(\chi\))

Existing rings

UMER Experiments

IREAP
From “Zero-Current” to Extreme Space Charge

0.6 mA  7.2 mA  24 mA  85 mA

Vacuum Pipe  Beam
UMER Electron Gun

TRIODE ELECTRON GUN: CATHODE DRIVEN, PIERCE TYPE

-200 -150 -100 -50 0 50 100
Nanoseconds

Milliamps

25 mm

K G

PE AP

Z=0

APERTURE PLATE

CATHODE AND ANODE GRIDS

IREAP
Capacitive Beam Position Monitor (BPM) and Phosphor Screen

17 BPM/Phosphor Screen (every 64 cm around ring)

0.1-0.4 mm, spatial res.  2 ns, temporal res.

Actuator

BPM right plate

Phosphor Screen

5.2 cm

B. Quinn, M. Walter
RMS Envelope Matching and Scaling

Bernal, Beaudoin, Y. Cui et al, NIM-A, 2004

100 mA

21 mA

9.0 mA
Diagnostics Tank at Beam Extraction

Slit-Wire Assemblies

Phosphor Screen (2.5 cm dia.)

Pepper-Pot

Faraday Cup

Energy Analyzer not shown

M. Walter, D. Lamb, W-T. Li
Beam Control System Software (H. Li)

Quadrupole Control

Dipole Control

BPM Control

Central Control Platform

IREAP

Steering Module

Skew Correction Module

Matching Module

Tomography Module
7.2 mA, 10 keV
7.2 mA

2xRMS Beam Semi-Axis (mm)

Dist. from Aperture Plate (m)

RC 1: 3.46 mm
RC 12: 2.72 mm
24 mA, 10 keV
The image shows a graph with data points for 2xRMS Beam Semi-Axis (mm) plotted against Dist. from Aperture Plate (m). The graph has two lines, one for RC1 and another for RC12. The data points indicate that the 2xRMS Beam Semi-Axis for RC1 is approximately 5.95 mm, and for RC12, it is approximately 4.70 mm. The graph is labeled with '24 mA' at the bottom.
Emittance Measurements

24 mA, 10 keV

χ=0.9, ε_{x,y}=30±5 \, \mu m (initial), a \approx 5 mm

ε_{x,y}= 42, 28 ±5 \, \mu m after 180^0
(straight section+18 FODO periods, or about 7.5 m)

ε_{x,y}= 30, 36 ±5 \, \mu m after 90^0
(straight section+8 FODO periods, or about 4.0 m)
Conclusions

- **Emittance** as well as *(extreme) space-charge* dominated e-beam transport demonstrated in a FODO ring.

- Highly **complex dynamics** of beam transport revealed: mismatch oscillations, beam rotation, halo formation, coupling of $x,y$ dynamics.

- **Future Work**: ring closure, detailed halo studies, **multi-turn**, energy spread evolution, longitudinal dynamics.