OVERVIEW OF ELECTRICAL SYSTEM FOR THE UNIVERSITY OF MARYLAND ELECTRON RING (UMER)*

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Abstract

Commissioning of the University of Maryland Electron ring (UMER) is currently underway. We discuss the various electrical systems of UMER. The power system includes 114 supplies for 70+ air-core magnetic quadrupoles, 36 Bending dipoles and 30+ steering dipoles as well as earth's field compensating coils. Systems for data collection comprise multiplexers and fast digitizers for diagnostics including 15 fast beam position monitors (BPMs) and video capture from fluorescent screen monitors. Several pulsers have been built in-house for injection and extraction magnets. The stringent timing scheme is also presented.

INTRODUCTION

The University of Maryland Electron Ring (UMER) is designed as a non-relativistic recirculating ring for studying the physics of space-charged dominated beams [1], [2]. Unlike most accelerators, UMER is designed to operate over a broad parameter space. As a result, the electronics must be flexible and rugged under many different operating conditions. Although UMER is a compact machine (11.52m circumference), it is unusually complex. The ring is comprised of 18 sections with four printed-circuit (PC) quadrupoles and two PC bending dipoles each. Further, 30+ steering dipoles and 18 bucking coils are used for recirculation. The matching section consists of a short solenoid and six PC quadrupoles. A pulsed wire-wound dipole and two pulsed PC quadrupoles are used for injection.

ELECTRON GUN

The UMER source is a cathode-driven, gridded electron gun with a Pierce configuration (Figure 1). The anode is held at ground potential and the cathode and grid are floated to the high voltage potential, nominally –10kV. This provides the accelerating voltage to the beam. A control DC voltage of 0V to 60V is applied between the cathode and the grid to prevent electron emission. Finally, a negative pulse of ~50V is applied to the cathode making it negative with respect to the grid, thus allowing electrons to be emitted. Great effort has been taken to ensure that the gun pulsing is synchronized to a null of the cathode heater voltage to within 1μs. This is to ensure that the beam is not born within a magnetic field from the 60Hz heater voltage. The current experimental set-up has limited UMER to operating at 30Hz. Future upgrades will allow UMER to operate at 60 Hz.

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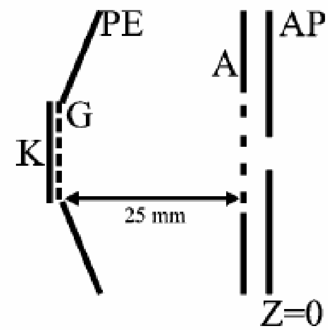

Figure 1: A highly simplified schematic (not to scale) of the UMER electron gun: cathode (K), control grid (G), Pierce electrode (PE), anode (A), and aperture plate (AP)

The pulse applied to the cathode is obtained from a simple pulse forming line (PFN) circuit. The length and dielectric constant of the line in the PFN determines the length of the pulse. Since the pulser is in reference to ground and then added to the high voltage by means of a standoff transformer, the length of the applied pulse can be readily adjusted.

The electron gun is normally operated in the space charge limited regime and can produce beams of various sizes and currents at a given accelerating voltage. Beam current can be manipulated by three methods. Firstly, we have the ability to change the cathode-anode spacing, which affects the current according to the Child-Langmuir's law. This gap is nominally set to 25mm. Next, the grid control voltage can be varied which limits the current by the retarding field. Lastly, various collimating masks on an aperture plate are included in the gun assembly close to the anode. The aperture wheel also includes pepperpot and 5 beamlet masks. It should be noted that all of these methods for changing beam size and current can be implemented in a matter of seconds on UMER.

Table 1: Summary of UMER Apertures

Aperture Radius (mm)	Beam Current (mA)
No Mask	100
2.85	85
1.5	24
0.875	7.2
0.25	0.7
5 Beamlet	30
Pepperpot	Used for Emittance measurements

The modular design of the apertures will allow us to replace or add apertures of different sizes and shapes of interest in the future.

MATCHING/INJECTION LINE

The matching/injection line, illustrated in Figure 2, consists of a short solenoid and six PC quadrupoles (Q1-Q6) over 1.5 m, approximately. Each of these magnets is independently powered (DC) and their polarity can be controlled via a manual switch. There are also six horizontal and six vertical short PC dipoles for steering the beam through the injection line. Since the beam is low energy and is thus susceptible to small magnetic fields, Helmholtz coils are used to balance all components of the earth's magnetic field in this part of the injection line.

Two small diagnostic chambers placed 28cm and 79cm from the source are available on the injection line. The first one contains a phosphor screen for imaging the beam and a set of mirrors used for viewing the cathode and reflecting a laser onto the cathode for photoemission studies [3], [4]. The second chamber contains a fast beam position monitor (BPM) [5] as well as a phosphor screen. The UMER BPMs are used for position and current-profile monitoring as well as for total-current measurements. The BPM/phosphor screen assembly is positioned via an actuator, allowing the operator to switch between diagnostics quickly. Further, a fast Bergoz current transformer is available between Q2 and Q3.

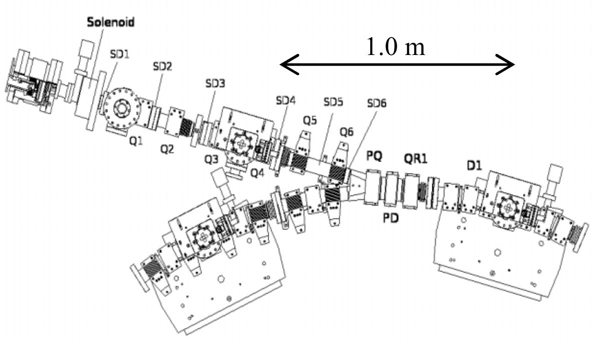

Figure 2: A scaled drawing of the UMER matching beam line, Y-Section and two ring sections showing magnet placement. Labels are explained in the text.

A novel approach for injecting the beam into the ring has been studied and successfully integrated into UMER [6]. For injection, the beam needs to be bent ten degrees. This is accomplished by using a pair of magnets. The beam is steered off center through a quadrupole (PQ in Fig. 2); this introduces a dipole component, giving the beam approximately a three-degree bend. The rest of the bending is accomplished by a pulsed wire-wound dipole (PD in Fig. 2). During recirculation the same scheme is employed with the beam being steered through the quadrupole with an offset in the opposite direction and the dipole having opposite polarity. This gives the beam a total of ten-degree bend in the opposite direction as that of injection. It should be noted that no compensation of the earth's field is implemented over the Y-section around the pulsed elements.

Unfortunately, due to manufacturing constraints, the Y-section must be oversized at the crotch, precisely where the injection magnets (PQ, PD) as well as the first ring quadrupole (QR1) must be positioned. As a result, these magnets must be oversized and require higher current. The oversized quadrupoles typically operate at 5.45A peak current, about three times the current of the normal-sized, DC-powered ring quads. In order to avoid overheating, the large-aperture quadrupoles are pulsed by means of a simple MOSFET-switched capacitive discharge with a high enough output resistance to create a 20μs flat top to the pulse. Since the lap time of the beam is 197ns, this is enough time for 100 turns. The peak currents required for the pulsed dipole (PD), on the other hand, are 25A for injection and –16A for recirculation. The magnitude difference is due to the vertical component of the earth's magnetic field, which helps to deflect the beam during recirculation, but opposes the bending during injection.

A pulser has been designed and implemented [7] to provide the necessary currents to the pulsed dipole. A 80μs, –16A pulse is created by means of a pulse forming network; then a 41A short pulse created by capacitive discharge is laid on top of it. A fall time <100ns is necessary to ensure the head of the beam is bent in the opposite direction by the time it comes around. Since the wire-wound dipole PD has a series inductance of 1μH and the fall time of the short pulse needs to be quick, it was decided to run the dipole with its halves in parallel.

Timing for the pulsed elements is crucial. The master trigger for the entire system is the cathode heater's zero crossing. This triggers several Stanford Research Systems DG535 delay generators for all of the pulsed elements. Some of these delays must be accurate to within 10s of picoseconds.

RING SECTIONS

Figure 3 illustrates a typical ring section with two ten degree bends, four quadrupoles, two bending dipoles, one horizontal steering dipole and Helmholtz coils for balancing the horizontal component of the earth's magnetic field. Fourteen of these sections are installed; they contain, as described before, a diagnostics station with a BPM/phosphor screen combination. Helmholtz coils are used on each ring section to buck out only the horizontal component of the earth's magnetic field. The vertical component actually helps to bend the beam in the ring. In fact, it provides one-third of the necessary field.

Three other sections have glass gaps for induction modules, which will be implemented during future upgrades. Development of resistive wall BPMs for these sections is currently underway. Finally, an extraction Y-section is under development. The existing large diagnostic chamber will follow this section. The large diagnostics chamber includes a slit-wire emittance meter,

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pepperpot, Faraday cup, energy analizer and a sliding phosphor screen. These diagnostics have been used in a previous experimental set-up of UMER.

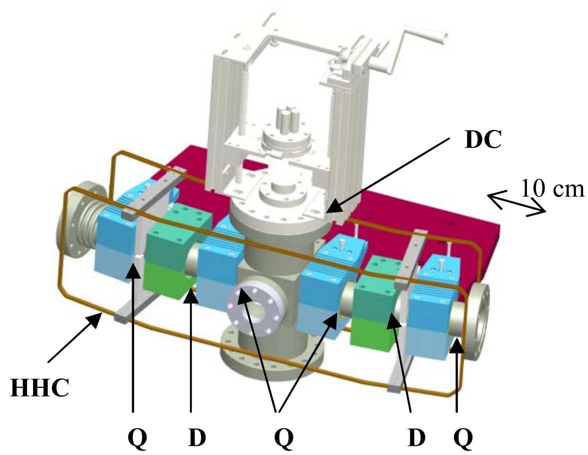

Figure 3: A scaled drawing of a UMER ring section, showing the locations of dipoles (D), quadrupoles (Q), Helmhotz coils (HHC and the diagnostic chamber (DC).

All of the magnets in UMER are air core printed circuits and have mounting blocks to aid in placement accuracy and to act as heat sinks. Each bending dipole is independently controlled while four quadrupoles of the same focusing polarity are connected together in series. In addition, each quadrupole is wired through a switch allowing it to be taken out of the series connection. This allows independent control of any quadrupole without affecting the rest. This capability is essential for conducting quadrupole-current scans, which are part of the alignment process [8] in UMER. Future upgrades will make possible computer control of quadrupole selection for scans. Furthermore, the polarity and strength of the short steering magnets used throughout the ring can be independently controlled with the aid of electronics that were designed and built in-house.

Thirteen 40 l/s ion pumps are used to maintain the 10^{-9} Torr vacuum needed for multi-turn operation. Since small magnetic fields may perturb the beam in UMER, all of the ion vacuum pumps, which contain permanent magnets, are mounted on long nipples keeping them 60cm from the beam line

CONCLUSIONS

The unique operating parameters of UMER require a complex electrical layout for powering and control of all elements. Flexible electronics systems have been successfully implemented in UMER. As a result, UMER has recently achieved multi-turn operation. Additional upgrades will be dictated by the needs, both in diagnostics and control, of this new, unexplored mode of operation in UMER.

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