Construction of a 200 keV Electrostatic Electron Accelerator
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The 200 keV electrostatic electron accelerator at Houghton College is being upgraded. The previous design used a makeshift electron gun that did not allow the beam to be easily controlled, and did not produce a well-defined beam spot. A new electron gun, taken from a RCA 3RP1 cathode ray tube, is being installed which will allow the beam intensity, focus and initial accelerating voltage to be remotely controlled. Using a 2000 V test system, a beam current of 0.1 μA was obtained into a beam spot of less than 1 mm diameter. The electron gun is to be remotely operated via an Ethernet-GPIB-RS232-fibre optic link to a BASIC Stamp-2 microcontroller inside the high voltage terminal of the accelerator. The microcontroller will set the voltages on the grids of the electron gun with a 12-Bit four channel DAC7624 digital-to-analog converter feeding four 4-transistor power amplification circuits which energize four EMCO G20 DC to HV DC converters.

History and Motivation
A small electrostatic accelerator that produces an electron beam or x-rays is having an upgraded electron gun fitted. In an electrostatic accelerator, electrons are accelerated through a large potential; in this case 200kV created by a van de Graaff generator. The original design used a 110.7 cm glass accelerating tube with copper rings placed evenly along the tube to create a uniform field. However, this design allowed charge to build up on the glass which deflected the beam. In addition, even with the filament off, the system would generate bremsstrahlung radiation due to uncontrolled high voltage discharges ionizing residual gas. A new accelerating tube solved these problems by using 51 alternating high density polyethylene and aluminum rings to stop charge accumulation. However, the homemade electron gun could not be properly focused, resulting in large uneven beam spot with average beam current of 0.36 μA. The end of the Bremsstrahlung radiation 180 keV. The upgraded new electron gun was taken from an RCA 3RP1 cathode ray tube, and will be controlled by a computer with supporting electronics inside the HV terminal.
Circuit Design

The electron gun is controlled by a microcontroller driving a HV power supply. The microcontroller is remotely programmed via an Ethernet-GPIB-RS232-fibre optic-RS232 link with appropriate converters. A BASIC Stamp-2 microcontroller runs a control program written in PBASIC, a subset of BASIC. This program accepts 12 bit values for the initial accelerating voltage, intensity grid voltage, and focus voltage, as well as turning on and off the filament. The microcontroller takes input from the RS232 link and outputs equivalent 12 bit voltage values in addition to two multiplexing bits at 5V. The microcontroller outputs are inputted into a 12-Bit four channel DAC7624 digital-to-analog converter which converts the digital input into four 0-2.5V latched analog outputs. The filament output is fed to a power transistor that powers the filament. The other three analog signals lead into three respective 4 power transistor amplification circuits which multiply the signal by a factor of 5.7 and are able to source 2 amps. After this, the signal for each element is fed to a respective EMCO G20 DC to HV DC converters which amplify the signal by a factor of 167. At this point the circuit is providing a less than 1 volt resolution with a voltage range of 0-2000V to the electron gun.
Electron Gun
The old electron gun was replaced with the electron gun from a RCA 3RP1 cathode ray tube. The glass envelope of the gun is mounted to a bronze flange with vacuum epoxy. As seen in Figure 4, the electron gun has 6 pins that are controlled by the microcontroller. Pin 12 is connected to the filament and is given a voltage of 6 volts AC. Pin 1 is ground. Pin 3 connects to the cathode, controlling intensity. It is given an adjustable voltage of approximately 2 to 6 volts DC. Pin 4 is connected to the focusing grid which allows adjustment of the diameter of the beam spot. Pin 4 is given a variable voltage of 100 to 400 volts DC. Pin 8 is connected to the electron gun’s accelerating grid. This provides the first push on the electron as it is accelerated. It is given a variable voltage of 500 to 2000 volts DC.

Figure 2-Picture of design and accelerating tube.
The accelerating tube of constructed of 51 alternating rings of high density polyethylene rings and 5052 aluminum of 0.6 cm thick and 0.3 cm thick, respectively. The polyethylene rings have an inner diameter of 5.08 cm and an outer diameter of 9.14 cm. The aluminum rings have an inner diameter of 3.81 cm and an outer diameter of 10.16 cm. The reason for the difference in radii is so stray electrons traveling down the accelerating tube do not strike the polyethylene rings and therefore charge the ring, disrupting the electric field of the accelerating tube. If an electron strike the aluminum ring, it will be conducted down the tube and therefore not disrupt the field. Each ring has four 0.6 cm hole symmetrically placed which were used to line the rings up on 4 Delrin rods during gluing. Each union of rings was glued inside the tube, as well at the joint on the exterior, and also between each ring.

The high voltage is supplied by a Van de Graaff generator oriented horizontally in the plane of the accelerator tube as seen in figure 5. The maximum current from the base to the sphere is 8 µA. The generating sphere, the aluminum sphere of the Van de Graaff generator, is split and transformed into a capsule containing the controlling circuit. The generator will be supported on an acrylic frame. The circuit board will be supported on a rectangular acrylic platform supported by two acrylic rods that span from the table, through the high voltage terminal, to the platform with in the capsule of the high voltage terminal.
**Operation**

The system is kept at a pressure of magnitude $10^{-5}$ to $10^{-7}$ torr by an Alcatel M2008A Rotary Forepump, cold trap, and Varian HSA2 diffusion pump. The fore pump achieves a lower pressure of the magnitude $10^{-2}$ torr and the addition of liquid nitrogen to the cold trap decreases the kinetic energy of the air molecules that come into contact with it, which disables their ability to overcome gravity. The diffusion pump aids in this process by spraying oil in a downward direction. The oil sticks to air molecules, causing them to become heavier. A fan mounted to the diffusion pump aids the condensing of the oil. The pressure within the system is monitored by a Convectron Pirani Gauge above to a pressure of $10^{-3}$ torr. Below this pressure, a Granville-Phillips 274005 Ion Gauge is used to measure pressure. The pressure is outputted to a Standford Research Systems Ion Gauge Controller (Model IGC100). Once a pressure of magnitude $10^{-4}$ to $10^{-5}$ torr is achieved, the electron gun is able to be turned on without the risk of burning the filament.

The Van de Graff generator supplies the high voltage. The filament is powered on and the controlling circuit supplies the electron gun components with the proper voltages. Electrons are accelerated through the accelerator tube and then impact the screen where a beam spot is seen. The screen comes from the same cathode ray tube that donated the electron gun. It is mounted to a brass flange with vacuum epoxy with a wire connecting the conductive layer of the screen to the brass flange. The screen is connected to the vacuum system via ceramic pipe with bolt on flanges. This allows the beam current to be measured by connecting an IBM 2210 Multimeter in series between the brass flange of the screen and ground. The beam can be focused and adjusted via the controlling circuit.

**Conclusion**

Recently, with the new electron gun, but without the accelerating tube, a 0.1 μA beam current with less than 1 mm diameter was achieved. Similar results are expected once the accelerating tube is installed. Currently the electronics and the high voltage terminal which houses them are being constructed. Future plans look toward allowing ions to be accelerated that could be used to produce neutrons.