

EXPERIMENTAL GUIDE: LONGITUDINAL BEAM PHYSICS UNIVERSITY OF MARYLAND ELECTRON RING (UMER)

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INTRODUCTION:

The longitudinal dynamics of highly space charge dominated beams can include launching space charge waves on the main beam to study density and energy modulations as well as studying the end erosion of the beam. In this experiment, we will introduce density and energy modulations on the beam in UMER and look at how these modulations propagate. We will look at the erosion of the beam and compare that to theory and also, if time permits, look at the focusing experiment.

BACKGROUND:

Section 5.4.7, 6.3.2 in M. Reiser's Theory and Design of Charged Particle Beams. Also, attached notes sheet.

EQUIPMENT:

The equipment needed is the Laser [UV 355nm laser], Wall current monitor at RC10 and the Tektronix oscilloscope at the console. In terms of the laser and other pulsed equipment, please ask the lab person in charge of your lab.

Laser safety: Though the laser and all the optics are well-shielded, exercise caution and ask for help when you need to change operating conditions of the laser. For all your experiments mentioned below, you don't have to go near the equipment.

PROCEDURE:

1. Setup the aperture for 7mA beam with **help**. Observe multi-turn operation of the beam in the scope. Show the cusp. Record the 7mA beam profile. A cusp is a point where the head of the beam and tail of the beam touch each other. Count how many pulses are there between the cusp and the start of the beam pulse? Record the length of time between those two points, using the cursors.

HW: Using the formula sheet, plot the theoretical time that it will take the beam head and tail to touch either other in the simple wave regime and also plot your data on the same graph.

2. Switch on the laser with **help** and notice how the space charge waves propagate on top of the beam over multiple turns as "fast" and "slow" wave. Record the profile. Ask for the perturbation current. Formula for C_s is shown in the sheet.

HW: Calculate the speed of C_s for each turn from the measured value and compare with theory.

Turn number #	Beam Current (mA)	Perturbation current (mA)	Speed of the waves (m/s)
1	7 mA		
2	7 mA		
3	7 mA		
4	7 mA		
5	7 mA		

3. Increase the perturbation current in small steps up to 2mA and record the beam profile for each case.

HW: Calculate the speed of C_s for each turn and compare with theory. How does changing the level of perturbation affect the speed of the waves?

Beam Current (mA)	Perturbation current (mA)	Speed of the waves (m/s)
7 mA	0.5 mA	
7 mA	1 mA	
7 mA	1.5 mA	
7 mA	2 mA	

4. Switch off the laser (ask for **help**).

5. **Energy perturbation experiment** In the previous experiment, we changed the beam current at the middle of the beam pulse and introduced a perturbation to the beam. Now, we will change the beam energy at the middle of the beam pulse and observe what happens. Ask operator to switch on the energy perturbation. Observe how the energy perturbation propagates as “fast” and “slow waves”.

6. Fix the perturbation energy (V). Ask the operator for the number. Record the beam profile and **fill up the tabular column for HW:**

Turn number #	Beam Current (mA)	Voltage (V)	Speed of the waves (m/s)
1	7 mA		
2	7 mA		

3	7 mA		
4	7 mA		
5	7 mA		

7. Increase the perturbation voltage in steps up to

HW: Calculate the speed of C_s for each turn and compare with theory. How does changing the level of perturbation affect the speed of the waves?

Beam Current (mA)	Perturbation voltage (V)	Speed of the waves (m/s)
7 mA		
7 mA		
7 mA		
7 mA		

8. Switch off energy perturbation.

9. (Optional) Focusing Experiment: During the experiments, the beam expands until it forms the “cusp”. Suppose we want to “focus” the beam, we apply ear-fields or end-field for focusing. Notice what happens to the beam ends i.e. the head and the tail when the beam is compressed. Take any data needed for your reports so you can explain what’s happening.

Repeat the experiment above with a high current beam 23mA

1. Setup the aperture for 23mA beam with **help**. Observe multi-turn operation of the beam in the scope. Count how many pulses are there between the cusp and the start of the beam pulse? Record the number:

2. Switch on the laser with **help** and observe how the speed of space charge waves increases compare to the previous case. Construct a table as above and verify with measurements.

HW: Calculate the speed of C_s for each turn using the formula. Did you notice the speed of space charge wave is higher when the beam current is higher? Why? Hint: Why is the speed of sound greater in solids compared to liquids and gas?

3. Increase the perturbation current in steps of up to 5mA and record the beam profile for each case. Construct a table as above and verify with measurements

HW: Calculate the speed of C_s for each turn and compare with theory.

4. Switch off the laser and switch on the energy perturbation and observe how the speed of space charge waves increases compare to the previous case. Construct a table as above and verify with measurements.

HW: Calculate the speed of C_s for each turn using the formula.

5. . Increase the perturbation voltage in steps up to(V).

HW: Record the beam profile for every step of increase in the perturbation voltage and calculate C_s for every case

Analysis:

- a. In the cusp experiment; does your data agree with theory? If it does or not, how could you explain why? Hint: look at the equations in the sheet.
- b. In typical accelerators, the energy of the beam is fairly high in the injector line. (Say = 1-10MeV). In such cases, evaluate how fast the space charge waves move? Explain the physics behind this?
- c. Suppose you have a 7mA beam with size equal to 1 cm. What happens to the wave's velocity? What is happening?

Simulation:

- a. MATLAB Code Part: Start the code by typing *Bunch_Expansion.m* at the command line. Plots should come up with velocity/current profiles. Open the m-editor so you can see the top lines of the code, the variables used to learn about end-erosion.
- b. Change the energy of the beam to 5keV, what happens?
- c. Change the current and radius to the pencil beam, what happens? Now change it to the 23mA beam. What happens?
- d. Change the pulse length to 50nsec and see what happens to the simulation result?
- e. How can you get more time before the beam head and tail touches each other? Which parameter or parameters can decrease the erosion rate?