INSTRUMENTATION FOR LOW ENERGY ELECTRON MEASUREMENTS

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Abstract

We report on the implementation of a beam charge, transverse beam position and bunch length measurement system for low energy electrons in the CESR injector. The core of the instrument is a piece of scintillating ceramic made from chromium doped alumina with a 200Å gold layer. Charge and current are measured when the beam is dumped onto the ceramic. Absolute beam position measurement is made by digitizing the image of the beam on the ceramic.

1 INTRODUCTION

The overall layout of the CESR injector is shown in Figure 1.[1] In the summer of 1995 when linac section 1 was removed to be replaced by a new SLAC section, we had the opportunity to install a package of instruments that enabled us to measure beam charge, transverse beam position and bunch length for low energy electrons ($150 - 200$ keV) in the CESR injector.

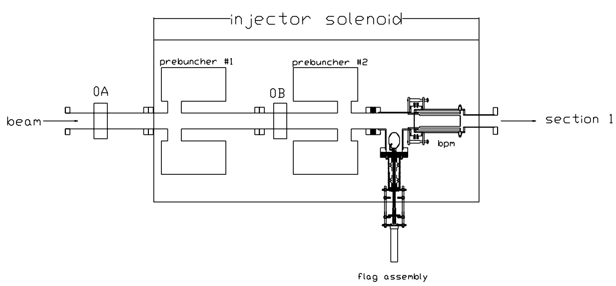

Figure 1: This is the overall layout of the injector. There are steerings in both the vertical and horizontal direction. By varying the phase and field strength of prebuncher 1 and 2, the amount of bunching and acceleration of the beam can be changed.

Central to the instrument package is a new flag made from chromium doped alumina with a 200Å thick layer. By dumping the bunches onto the flag, charge, bunch length and transverse position of the beam can be directly measured. Upstream from the flag is a stripline beam position monitor (BPM) which is used for non-destructive measurement of the charge and transverse position of the beam. To accurately measure the charge dumped on the flag, a temporary Faraday cup was also installed further downstream from the flag. After the flag was cross calibrated with the Faraday cup, the Faraday cup was removed for the installation of the new SLAC section.

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2 CHARGE MEASUREMENT WITH FLAG

Two methods of measurement were used to calibrate the flag with the Faraday cup

- Alternating current (AC) method where we numerically integrate the gun pulse on a digitizing oscilloscope.
- Direct current (DC) method where we directly integrate the current using an electronic integrator. See Figure 2 for the essential differences of the two methods.

The AC method allows us to bias the flag so that backscattering from the electrons is minimized.

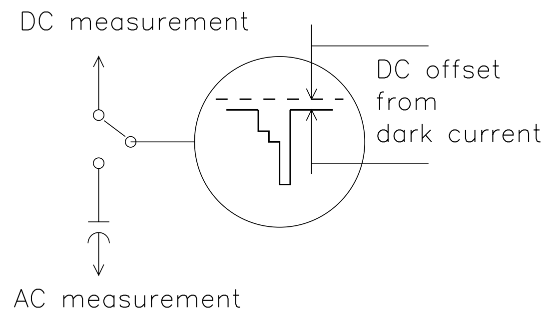

Figure 2: The essential difference between the AC and DC method is the capacitor which removes the dark current d.c. component in the AC method.

2.1 Dark Current

The main errors in the charge measurement comes from the large dark current component. Dark current is the DC current that is present when the gun is not pulsed and the gun grid is held at a bias of 300 V. The dark current comes from grid contamination of the gun. Figure 3 shows the dark current as seen on the flag.

2.2 Results

The graphs showing the cross-calibration curves are shown in Figure 4. The large error bars for the low current measurements come from the dark current component in the measurement. Since the flag is upstream from the Faraday cup, it intercepts more charge.

3 BUNCH LENGTH MEASUREMENT

By dumping the bunches onto the flag, we can measure the bunch length. Figure 5 shows the result after numerical filtering. The bandwidth of the system is such that we can clearly see bunches separated by 28 ns.

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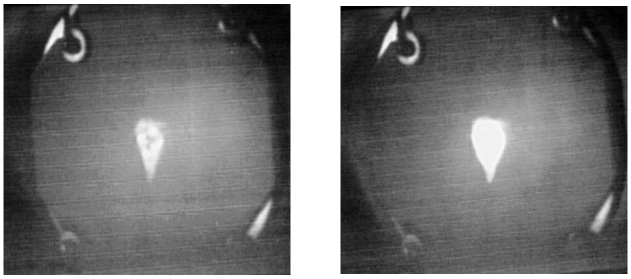

Figure 3: These photographs show how the structure of the dark current sources evolves through time. These photographs were taken 5 hours apart with the earlier photograph the left. Clear structural changes took place during the intervening period. These structural changes come from cycling the beam on and off during the 5 hours.

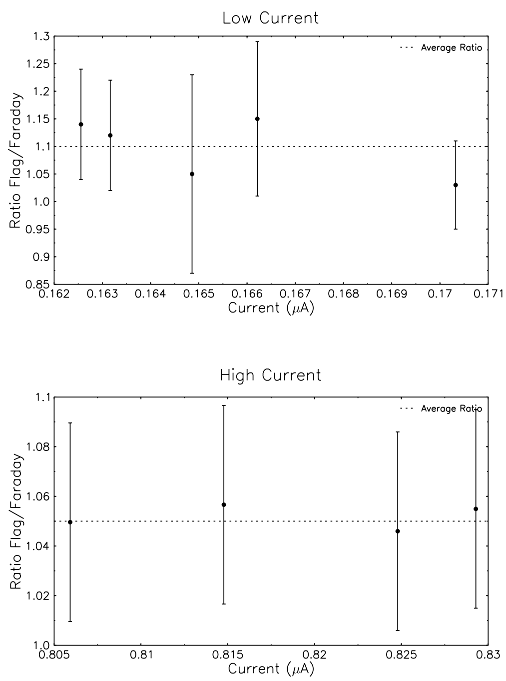

Figure 4: These two figures show the comparison between the flag and Faraday cup measurements using high current and low current conditions with the DC method. The flag intercepts more charge than the Faraday cup because the flag is upstream w.r.t. Faraday cup.

4 TRANSVERSE POSITION MEASUREMENT

The transverse position of the beam can be measured by measuring the centroid of the beam on the flag. Unfortunately, the large dark current component necessitated some simple graphics manipulation. The procedure for obtaining the centroid is shown in Figure 6. The BPM is then calibrated with the transverse position obtained from the flag and then beam-transported to the BPM.

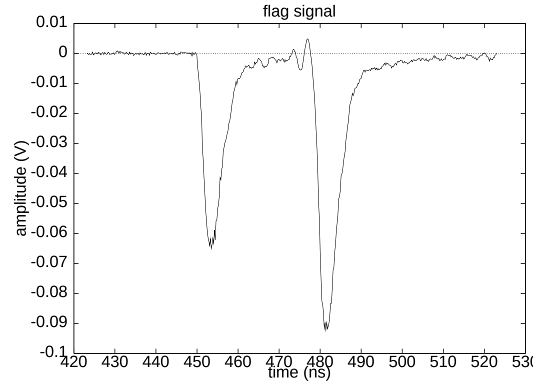

Figure 5: Bunch trains 28 ns apart as seen by the flag.

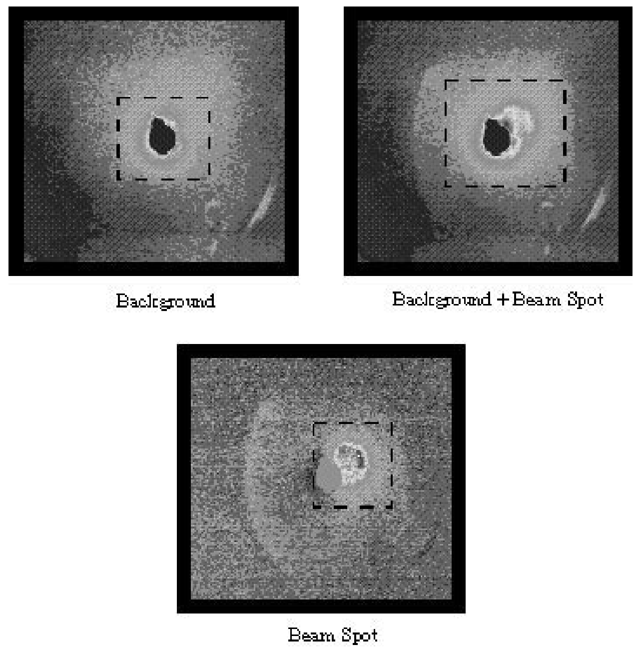

Figure 6: We show the process of digitization and image manipulation here: (i) background image is taken with the dark current, (ii) an image with both the dark current and the beam is taken, (iii) finally an image difference reveal the beam spot.

5 CONCLUSION

We have described an instrument package that is able to measure charge to better than 10% and differentiate bunches that are spaced 28 ns apart. Transverse position of the beam can either be measured with the flag or the BPM.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

[1] The CESR Injector, C.Y. Tan, thesis 1997.