

# PHOTOCURRENTS IN THE VERTICAL ELECTROSTATIC SEPARATORS AT CESR

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## Abstract

At CESR a pair of vertical separators are used to separate the two beams vertically at the symmetry point, in the north, of the interaction point in the south. They are 2.7 meter long and each one is providing a 1.0 mrad kick for a differential voltage of 100 KV between the electrodes. One side of each separator is exposed to the high flux of synchrotron radiation from a soft bend, 140 meter radius, magnet and a hard bend, 34.8 meter radius, magnet. The radiation generates large amount of photoelectrons which are converted to a large photocurrent. For a beam current of 150 ma the photocurrent is 1.2-1.5 ma. It caused, a few times a day, a partial drop in the high voltage which caused a vertical beam blow up and beam loss. In addition the photocurrent was increasing the heat load of the positive electrode by 25 percent. In the paper we will show how we were able to suppress the photocurrent almost to zero. As a result we have seen an increase in the life time of the beams and as well an increase in the luminosity.

## 1 INTRODUCTION

The main sources of synchrotron radiation that enters the vertical separator that is located to the east of the symmetry point are the two bending magnets B47E1 (R=140.62 m) and B47E2 (34.817 m), while for the separator that is located to the west of the symmetry point it is B47W1 and B47W2. The electrons which travel from east to west radiate into the east separator and the positrons which travel from west to east radiate into the west separator. When operating CESR with large horizontal closed orbit distortion "pretzel" that is needed for multibunch operation in colliding condition, synchrotron radiation from positrons generated in B47W1&2 can also enter the east separator and synchrotron radiation from electrons generated in B47E1&2 can also enter the west separator. This occurs because of the large beam offset in the bending magnets; some of the radiation misses the radiation absorber and thus is able to reach the other separator. When the synchrotron radiation enters the separators there are four different possibilities to generate photoelectrons but only two of them will lead to photocurrents. A. If the photons hit the outer tank near the positive voltage electrode the emitted photoelectron will be accelerated to the positive electrode and photocurrent, that is supplied by the positive electrode power supply, will be generated. B. If the photon hit the high voltage positive electrode the photoelectron will not be able to escape and it will be pulled back by the high positive voltage of the elec-

trode and no photocurrent is generated. C. If the photon hit the outer tank near the negative electrode the photoelectron will not be able to escape and no photocurrent is generated. D. If the photon hit the high voltage negative electrode the photoelectron will be accelerated either to the outer tank which is at ground potential or to the high voltage positive electrode. In both cases a photocurrent is generated. If the photoelectron is accelerated to the outer tank the photocurrent is supplied by the negative electrode power supply. On the other hand if the photoelectron is accelerated to the positive electrode the photocurrent is supplied by the negative and the positive high voltage power supplies. For summary, the current we measure on the high voltage positive power supply is the sum of the photocurrent generated by the photons hitting the outer tank near the positive electrode and the photocurrent generated by photons hitting the negative electrode. While the current we measure on the high voltage negative power supply is equal to the photocurrent generated by the photons hitting directly the negative voltage electrode.

## 2 THE MEASURED PHOTOCURRENTS IN THE EAST AND THE WEST VERTICAL SEPARATORS

The vertical separator cross section can be seen in Figure 1. In the separators the top electrode is positive while the bottom electrode is negative. The measurements were carried out in three steps. First we measured the effect of the electron beam only, second we measured the effect with positron beam only and last we measured it with both beams. In all the three measurements each beam had eighteen bunches composed of nine trains two bunches per train, with eight ma per bunch. The measurements were done in colliding conditions which had large horizontal closed orbit distortion. Each electrode has its own high voltage power supply that can be regulated independently. The results of the measurements of the photocurrents with 144 ma of one beam in CESR at a time can be seen in the upper part of table 1, while the results for both beams in CESR at the same time with 144 ma per beam can be seen in the lower part of table 1.

## 3 METHOD TO SUPPRESS THE PHOTOCURRENTS

From the results of the measurements with electrons only, which are shown in the second row of table 1, we can also see photocurrent in the west separator. That means that some of the synchrotron radiation generated in the east

\* Work supported by the National Science Foundation

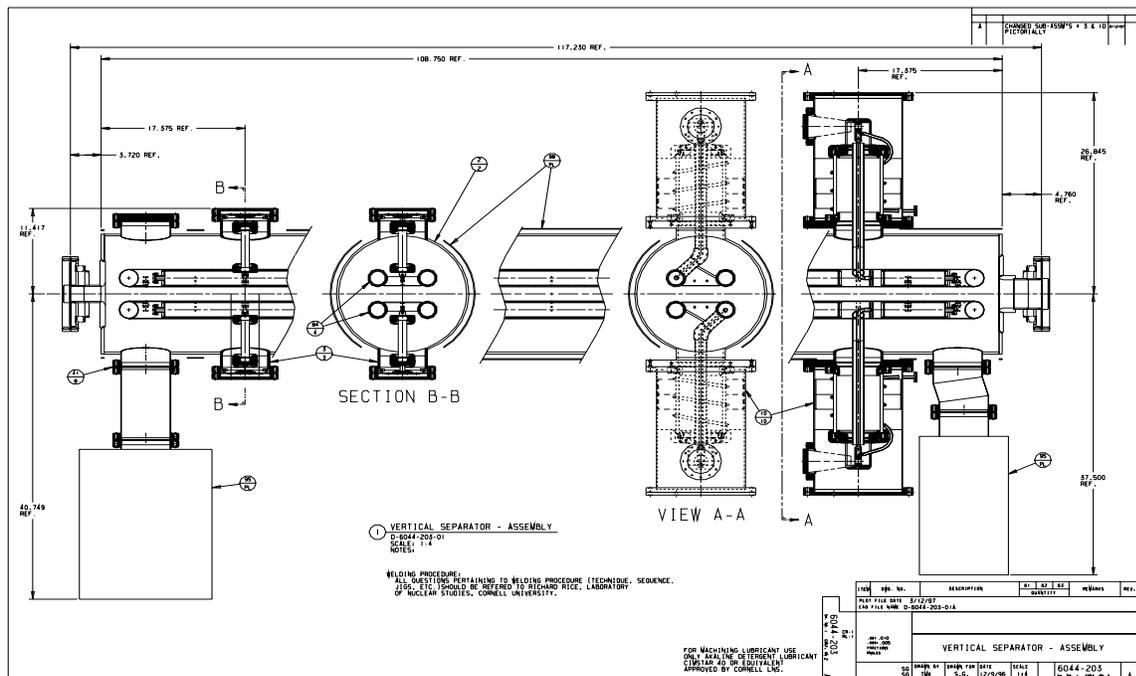


Figure 1: The Vertical Separator Cross Section

Beam in CESR	EAST		WEST		Conditions
	TopEle.(ma)	Bot.Ele.(ma)	TopEle.(ma)	Bot.Ele.(ma)	
e -	0.75	0.10	0.20	0.10	OFF Energy (Oct.8.96)
e -	0.70	0.10	0.40	0.00	ON Energy (Oct.15.96)
e +	0.15	0.10	0.80	0.00	ON Energy (Oct.15.96)
e+& e -	1.35	0.60	1.10	0.07	ON Energy (June.17.96)
e+& e -	0.90	0.15	1.10	0.00	ON Energy (Oct.5.96)
e+& e -	0.90	0.15	1.10	0.10	OFF Energy (Oct.8.96)

Table 1: The Measured Photocurrents in the Top(+) and the Bottom (-) Electrodes in the East and the West Vertical Separators, with only one Beam in CESR Upper part of the Table and Two Beams in CESR lower part of the Table

bending magnets B47E1&2 entered the west separator hitting its south end. The resulting photoelectrons were drawn to the top (positive) electrode generating 0.4 ma of photocurrent (option 1). While from the measurements with the positrons, the photocurrents in the east separator are low meaning that very little of the synchrotron radiation generated by the positrons in the west bending magnets enters the east separator. From the measurements that were done on June 17, 96, with both beams in CESR, it can be seen that the bottom (negative) electrode of the east separator had 0.6 ma of photocurrent. This photocurrent is generated by photons that are hitting directly the negative electrode. We have found that the source of these photons are the positrons in the west (option2). The effect of the electrons on the west separator and the positrons on the east separator depend on the optic lattice that is used. We have found that we can reduce by more than 70% the photocurrents induced by the opposite beam by introducing local vertical bumps in the bending magnets in the positrons op-

tics in the west and in the electron optics in the east. The Oct. 5, 96, measurements had such bumps which reduced the photocurrent of the negative electrode of the east separator from 0.60 ma to 0.15 ma. At the same time the photocurrent of the positive electrode decreased by the same amount from 1.35ma to 0.9 ma, as can be seen in lower part of table 1. This indicate that the photoelectrons from the negative electrode are accelerated to the positive electrode and not to the ground. In the vertical separators the radiation absorber is made of copper block with a shallow groove and is water cooled. The center of the absorber in the vertical direction coincide closely with the zero potential plane which is located in the mid plane between the positive and negative electrodes. As a result of this the top half of the absorber is in a positive electrical field regime while the lower half is in a negative electrical field regime. Because the groove in the absorber is shallow, any photoelectron generated by photon hitting the top half of the absorber is able to escape and be drawn to the positive electrode. An

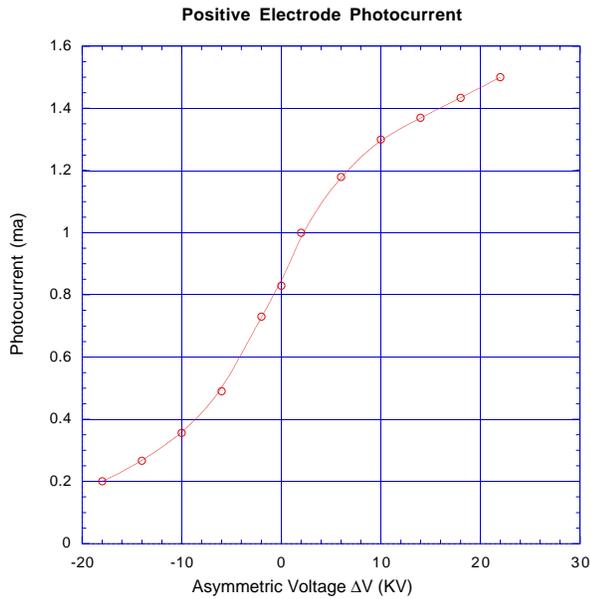


Figure 2: The Measured Photocurrent of the Positive Electrode as Function of the Asymmetric Voltage  $\Delta V = V^+ - V^-$

effective way to stop the photoelectrons from reaching the positive electrode is to move the zero potential plane up so the whole absorber will be in the negative electrical field regime and the photoelectrons will not be able to escape. One way to achieve this is to operate the separator in an asymmetric mode i.e., increase the voltage of the negative electrode (bottom) and by the same amount decrease the voltage of the positive electrode (top) so that the vertical kick to the beams will be the same but the zero potential plane will move up. Results of such an asymmetric mode of operation of the separator can be seen in Figure 2, where by moving the zero potential up the photocurrent of the positive electrode was reduced from 0.83 ma to 0.22 ma. On the other hand, when we moved the zero potential plane down by increasing the positive voltage and decreasing the negative voltage by the same amount, the photocurrent of the positive electrode was increased from 0.83 ma to 1.5 ma. Another way to stop the photoelectrons from reaching the positive electrode is by placing an external magnet across the absorber. When operating in symmetric mode  $\pm 45$  KV with an external dipole magnet, which has 230 Gauss at the center, across the absorber the photocurrent of the positive electrode was reduced from 0.75 ma to 0.20 ma. The photocurrent was further reduced to 0.1 ma by changing the electrode voltages from  $\pm 45$  KV to -50 KV and + 40 KV.

#### 4 SUMMARY AND CONCLUSION

Any time a new optic lattice is implemented in CESR, the effect of the synchrotron radiation generated by the opposite beams, i.e. positron beam on the east separator and electron beam on the west separator, is reduced by intro-

ducing local closed vertical bumps in the lattice (a bump in the west for the positrons and a bump in the east for the electrons). As we have shown above, each one of the methods; moving the zero potential plane up or the external dipole magnet across the absorber, is very successful in suppressing the photocurrents in the vertical separator. But the combination of both methods has a number of advantages because of the following reasons: A. using only asymmetric voltages on the electrode will require more than 20% increase in the voltage of the negative electrode compare to symmetric voltages, which will limit the maximum vertical kick that the separators will be able to provide. B. In addition, by moving the zero potential plane up by a large amount, the electrical fringe fields at the ends of the separator will be stronger at the beam location. Thus having larger effect on the beam dynamic. On the other hand using the external magnets only will not stop the photoelectrons generated by the radiation hitting the other end of the separator generated by the opposite rotating beam. Operating CESR with electrons and positrons in collide mode with total current of 150 ma per beam the photocurrents in both separators were reduced to less than 0.2 ma for the positive electrode and 0.1 ma for the negative electrode. This was achieved by using an external magnet across the absorber combined with asymmetric voltage. These remaining photocurrents are mainly generated by scattered photons from the beam chamber into the separator either by mirror scattering which will hit the inside tank wall and the photoelectrons will be drawn to the positive electrode or Rayleigh large angle scattering where part of them will hit the negative electrode and generate photocurrent in both electrodes. Since the photoelectrons from the negative electrode will be accelerated to the positive Electrode. The estimated photocurrents for CESR upgrade "phase III" which is designed to have 500 ma per beam are; 0.65 ma for the positive electrode and 0.35 ma for the negative electrode. We have measured the effect of the external magnet and the asymmetric voltage on the electrodes in three different ways: 1. We did not see any measurable changes in the beams orbit. 2. The horizontal and the vertical tunes did not change by more than 30 Hz. 3. The vertical chromaticity did not change. On the other hand we saw improvements in the beam life time and more important the number of beam losses due to high voltage micro arcs in the vertical separators became very small. As a result the total integrated luminosity was increased.