CHANGES IN ELECTRON CLOUD DENSITY WITH BEAM CONDITIONING AT CESRTA*

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Abstract

We compare measurements of electron cloud (EC) buildup in uncoated and TiN-coated aluminum vacuum chambers as a function of integrated beam dose up to 1140 amp-hours. The EC density in newly installed bare aluminum chambers increases with beam dose, while the EC density in the TiN-coated chambers decreases with dose under the same beam conditions. Several techniques are used to monitor EC buildup. These include shielded pickups that measure the flux of cloud electrons onto the beam-pipe wall, and a TE wave resonance technique that measures the EC density within the volume of the beam-pipe. These measurements were made at the Cornell Electron Storage Ring, which has been reconfigured as a test accelerator CESRTA, providing positron and electron beams with energies ranging from 2 GeV to 5 GeV and a variety of bunch train configurations.

INTRODUCTION

New chambers were installed at three locations in the Cornell Electron Storage Ring Test Accelerator (CESRTA) in August 2012 as shown in Fig. 1. We have previously reported on the effects of beam conditioning measured immediately after chamber installation and then again after a significant beam dose of up to 1140 amp-hours [1]. Data with beam dose that is between these two extremes is presented here in order to estimate the dose required to obtain this conditioning. Table 1 shows the number of amp-hours for each beam. The chambers in L3 were let up to atmosphere as part of a separate project in January 2013, but the chambers at 15W and 15E have been under vacuum throughout this period. The table shows two values for the beam dose in April 2013 to reflect this.

Using the TE wave technique, data was collected in the TiN and bare aluminum chambers in L3 as well as the bare aluminum chamber at 15E. The raw data is in the form of phase modulation sideband amplitudes from which the peak electron cloud (EC) density can be calculated [2, 3]. The 10-bunch TE wave data taken in this study use 14 ns spaced bunches.

Shielded pickups (SPU) collect data from the TiN chamber at 15W and the bare aluminum chamber at 15E. This data is in the form of an oscilloscope trace as the SPU samples the flux of cloud electrons onto the vacuum surface [4]. For the purpose of plotting, the averaged scope trace is integrated to obtain the charge into the 50 Ω scope input for each turn (including the preamplifier voltage gain of 100). The data presented here is from two bunches of equal charge spaced by 14 ns. A turn at CESRTA is 2.5 μs and data is recorded with a 100 ns span, which is enough time to capture the non-zero signal from two bunches.

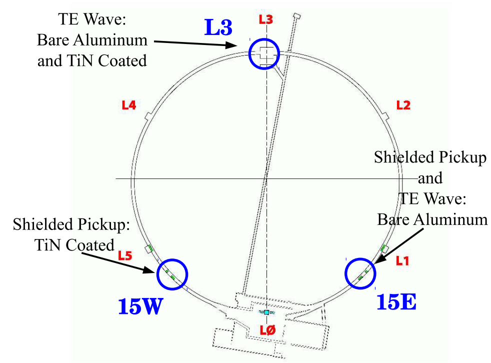

Figure 1: This sketch of the CESRTA storage ring shows the location of detectors used in this study: SPU in a chamber with TiN coating at 15W; SPU and TE wave measurements in the same aluminum chamber at 15E; TE wave measurements in the grooved TiN and bare aluminum chambers of L3.

Table 1: Beam Dose After Chamber Installation

Date (mm/dd/yy)	e- Amp-Hr	e+ Amp-Hr
08/22/12:	0.0068	0.028
08/23/12:	0.411	0.140
10/10/12:	167.9	166.2
11/19/12:	305.6	305.6
12/13/12:	306.0	308.0
(04/17/13):	(251.6)	(269.4)*
04/17/13:	558.8	579.7

*Since L3 at atmosphere during January 2013

CONDITIONING OF TITANIUM NITRIDE

There are two TiN-coated chambers in this study: the grooved chamber at L3 where there is TE wave data and the 15W chamber with SPU data. Figure 2 gives examples of the recorded 2-bunch SPU data at 8 mA/bunch. The signal from the first bunch peaks before 20 ns and is mostly composed of photo-electrons produced in the empty chamber. The larger second bunch signal at about 30 ns includes

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photo-electrons, but is dominated by the cloud electrons produced by the first bunch that are accelerated into the detector by the second bunch.

As a guide for interpretation of the SPU signals, simulations with ECLOUD [5] have shown that an increase in both the first and second bunch signal generally indicate an increase in the quantum efficiency for producing photo-electrons. Changes in the second bunch signal for the same first bunch signal generally indicate a change in the secondary emission coefficient. The data from April 2013 of Fig. 2 suggest a reduction in quantum efficiency with extensive conditioning, since there is a reduction in both the first and second bunch signals. The very early conditioning from August 22-23, 2012 (0.5 amp-hours) on the other hand appears to have an unchanged first bunch signal, while the second bunch signal is reduced by ten percent or so.

The integral of traces such as those shown in Fig. 2 become data points of Fig. 3 giving the SPU signal versus total beam current. The 2-bunch SPU data from the TiN chamber of Fig. 3 shows a noticable reduction in the SPU signal between the first beam in the storage ring on August 22nd and measurements taken the following day. Records also show that the vacuum improved under the same conditions from 100 nT to about 30 nT with a total beam dose of 0.551 amp-hours. The later measurements show small progressive reductions in the SPU signal with beam dose.

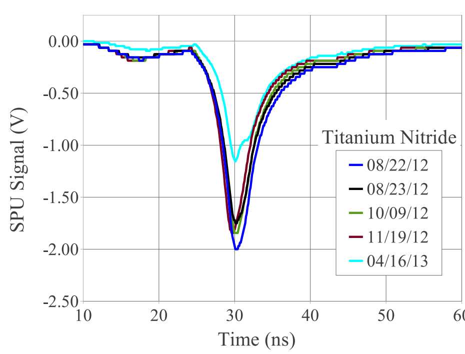

Figure 2: These plots are part of the 2-bunch SPU data that was taken in the TiN-coated chamber at 15W with 16 mA total positron current (8 mA/bunch = 1.28×10^{11} positrons/bunch).

The 10-bunch TE wave data from the L3 grooved TiN chamber in Fig. 4 is somewhat different. There is a step change in the EC density between the August 2012 data and all of the remaining measurements. The EC density measurement in October at 334 amp-hours is only slightly higher than the remaining measurements. This chamber was let up to atmosphere during maintenance in January 2013, so the April 2013 data in L3 corresponds to 521 amp-hours for that chamber. The TiN chamber at 15W (Fig. 3) had a total of 1140 amp-hours.

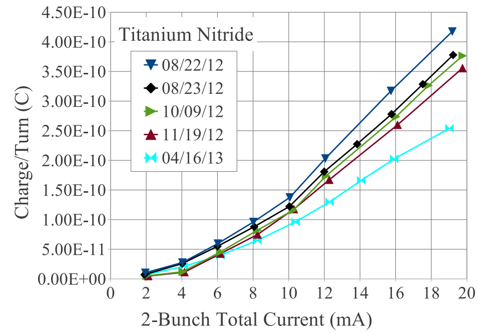

Figure 3: 2-bunch SPU data from the TiN-coated chamber at 15W (see Fig. 2) is integrated to obtain charge/turn. The data shows monotonic conditioning with beam dose. This includes the earliest conditioning with less than 0.5 amp-hours.

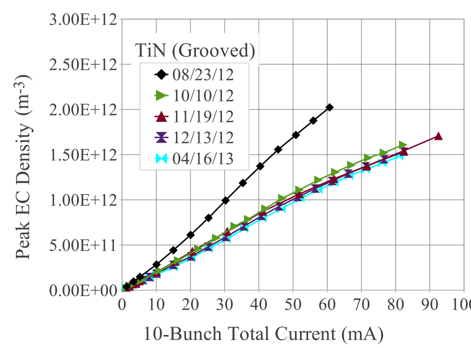

Figure 4: TE wave data with ten bunches from the grooved TiN-coated chamber at L3.

CONDITIONING OF BARE ALUMINUM

There are two bare aluminum chambers in this study: the grooved aluminum chamber in L3 with TE wave measurements and the 15E chamber where both TE wave and SPU measurements are made. Figure 5 shows some of the SPU data taken in the bare aluminum chamber at 15E. Following the interpretation used in the previous section on TiN SPU signals, Fig. 5 shows an overall increase in the signal from August 2012 to April 2013. There is an increase in both the first and second bunch signals, suggesting that this is due to an increase in quantum efficiency. The very early conditioning data (in the first 0.5 amp-hours) from August 22-23, 2012 shows a decrease in both the first and second bunch signals, suggesting a decrease in quantum efficiency. There were also substantial changes in the vacuum during the measurements on these two days, from 300 nT down to 30 nT at the peak currents. So it is possible that some of the electrons were produced by ionization.

Integrating the SPU signals, the charge/turn values are plotted versus total current in Fig. 6. As with the individual scope data plots, the trend of SPU signal versus current shows a decrease in signal amplitude with less than

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0.5 amp-hours, but after this, there an overall increase of EC density in the aluminum chamber with dose.

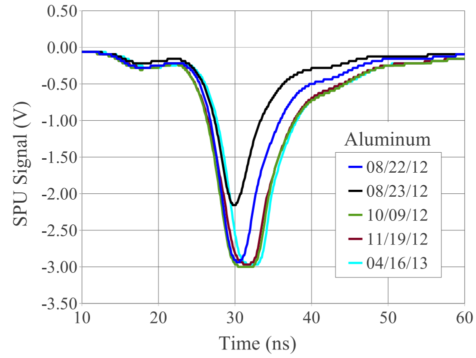

Figure 5: These plots are part of the 2-bunch SPU data in the aluminum chamber at 15E that was taken with 16 mA total positron current (8 mA/bunch = 1.28 $\times$ 10^{11}positrons/bunch). The preamplifier output is limited to 3 V resulting in some flattening of the highest amplitude signals.

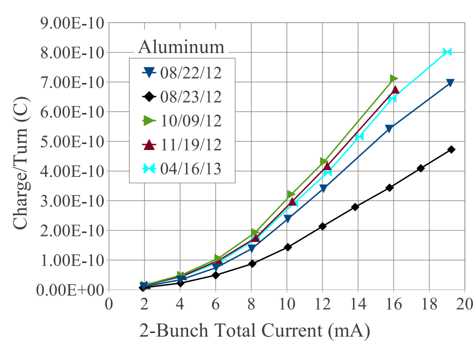

Figure 6: SPU two bunch data from the bare aluminum chamber at 15E shows an overall increase in signal with dose.

The 10-bunch TE wave data from the aluminum chamber at 15E is shown in Fig.7 and agrees with the SPU data in that the EC density becomes higher than its initial value after less than 170 amp-hours. No very early (less than 0.5 amp-hour) TE wave data is available in this data set. Data from the L3 grooved aluminum chamber in Fig. 8 shows a similar increase in EC density of about 40 percent after the earliest data.

CONCLUSIONS

Data taken using two very different techniques give similar information about the conditioning of bare aluminum and TiN-coated chambers. Bare aluminum shows a significant increase in EC density after modest conditioning and is mostly unchanged thereafter. There is some disagreement between the two techniques in data from TiN-coated chambers as to whether or not these chambers continue to

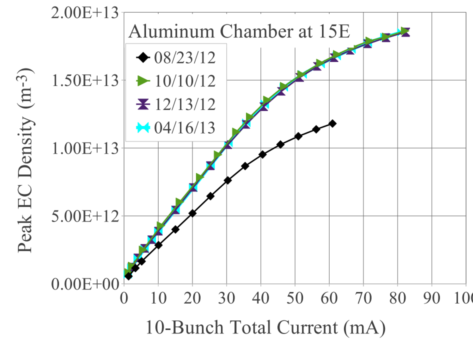

Figure 7: TE wave ten bunch data from the bare aluminum chamber at 15E shows a step increase of about 40 percent in EC density after the earliest measurement.

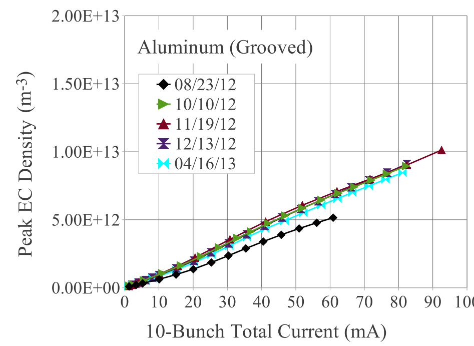

Figure 8: TE wave data from the grooved aluminum chamber in L3 also shows a step increase in EC denstity after the earliest measurement.

condition with beam dose. Interpretation is more difficult in this case because the TiN chambers have different photon dose and vacuum histories.

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