ELECTRON CLOUD MEASUREMENTS USING A TIME RESOLVED RETARDING FIELD ANALYZER AT CESRTA*

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Abstract

The Cornell Electron Storage Ring has been reconfigured as a test accelerator (CESRTA) with positron or electron beam energies ranging from 2 GeV to 5 GeV. An area of research at CESRTA is the study of the growth, decay and mitigation of electron clouds in the storage ring. With a Retarding Field Analyzer (RFA), cloud electrons pass into the detector through an array of small holes in the wall of the beam-pipe. The electrons are captured by several collectors, so that the electron flux can be measured as a function of horizontal position. Up to now, we have time averaged the collector currents to provide DC measurements. We have recently designed and constructed a new Time Resolved RFA (TR-RFA), where the collector currents can be observed on the time scale of nanoseconds. We present a summary of the design, construction and commissioning of this device, as well as initial beam measurements at CESRTA.

INTRODUCTION

The Time Resolved Retarding Field Analyzer (TR-RFA) is a natural extension of two other instruments that have been very successful in the study of electron clouds (EC): Shielded Pickups (SPU) and Retarding Field Analyzers (RFA).

The SPU is simple device for sampling the time resolved growth and decay of the electron cloud [1, 2]. The SPU measures the flux of cloud electrons into the beam-pipe wall by allowing a sample of this current to pass into the detector through an array of small holes. The holes also isolate the SPU electrode from the direct beam signal – the depth to diameter ratio of the holes of about 3:1 provides significant attenuation [3]. This is especially important when recording time domain data. Time domain information has been used to map the growth and decay of the electron cloud, measure the effectiveness of mitigation techniques and to constrain the parameters used in electron cloud simulations [4].

In the case of a Retarding Field Analyzer (RFA), cloud electrons also enter the detector through an array of holes. In addition, a retarding grid can be biased negatively to suppress low energy electrons from reaching the collectors [5]. The current of electrons into the detector is time averaged and recorded. The devices installed at CESRTA have segmented collectors that allow this electron current to be measured as a function of horizontal position [6]. These devices have been useful in measuring the effectiveness of mitigation techniques, the horizontal distribution of the electron cloud and in constraining EC model parameters [7].

The Time Resolved RFA (TR-RFA) combines the properties of these two devices by providing a time resolved collector signal and a grid that can be used to obtain additional energy information. Figure 1 shows a cross section of the beam-pipe with a TR-RFA detector. The middle of three grids is used to provide the retarding field. There are nine collectors, each 0.6 cm wide and 7.5 cm long, etched on a kapton flex circuit that are connected directly to individual SMA feed-throughs as shown in Fig. 2. During data taking, the collectors are biased at +50 V to prevent secondary electrons from leaving the collector surface.

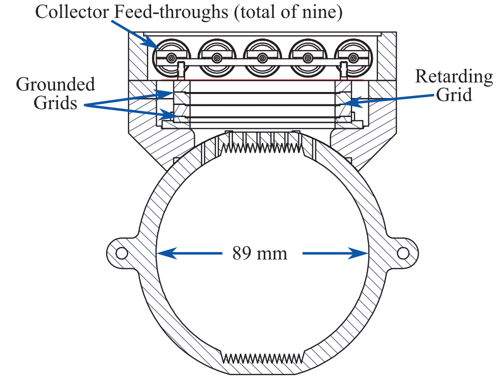

Figure 1: A cross section of the TR-RFA shows the geometry of the grooved beam-pipe extrusion and the relative location of grids and collectors.

INITIAL BEAM TESTS

Early in 2012, two prototype TR-RFAs were installed at CESRTA in beam-pipe of round cross section, one made of bare aluminum, the other with the vacuum surface coated with TiN. They were located in two of four chicane dipole magnets, replacing standard RFAs that had been in use previously. A bias of +50V was applied both to the retarding grid and the collectors during initial data taking. Cables 25 cm long route each collector signal to cascaded pairs of

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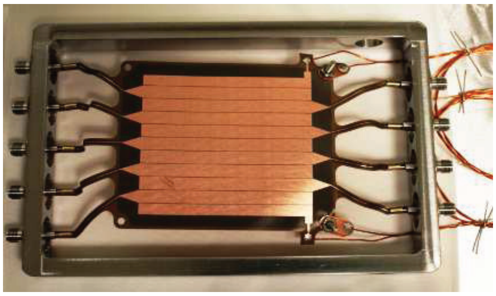

Figure 2: Bottom view of the nine collectors on a kapton flex circuit. Each collector is connected to an SMA feedthrough. Collectors are numbered in order of horizontal position, with 1 toward the outside of the storage ring.

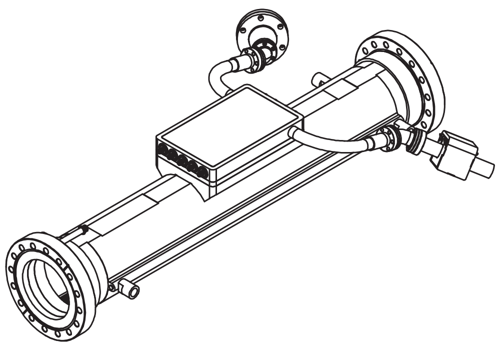

Figure 3: A test chamber with a TR-RFA installed on round beam-pipe. The thin pipe on the right connects to a small ion pump. The thin pipe on the left carries wires for biasing the grids.

Mini-Circuits ZFL-500 amplifiers for a voltage gain of 100. The amplified signals are sent out to an array of Agilent DSO6054L oscilloscopes where data is averaged for 8k traces. The accelerator timing system provides the scopes with a trigger on each turn of the stored beam.

Initial results can be seen in Fig. 4, where the signal from the TR-RFA in the bare aluminum chamber is shown with and without a dipole magnetic field of 790 G. The beam in the storage ring consisted of a 10 bunch train of positrons at 5.3 GeV with 14 ns spacing. A witness bunch is also present 112 ns after the train. Without magnetic field, collector 4 (near the horizontal center of the beam-pipe) has the largest signal. When the field is turned on, all of the signals are reduced in amplitude, but collector 4 is reduced more than the others. This suppression of the central signal with magnetic field has also been seen in measurements with standard RFAs [8].

The peak voltage of each collector is plotted for each chicane magnet setting between zero and 790 Gauss in Fig.5. The signal in all collectors is reduced considerably even with low magnetic fields. This is probably due to the deflection of the low energy photo-electrons (produced by synchrotron light) so that they do not propagate out into the region of detector sensitivity. As the magnetic field increases, the signal from collector 4 decreases steadily as other signals either remain steady or increase.

Generally, the performance of the prototypes was successful although the direct beam signal is significant. There was also a resonance in the detectors due to details of grounding that could be excited by the direct beam signal. Initial data was taken only after some effort was made to reduce the ringing of the detector with termination of the grounded grids and filtering of the retarding grid bias.

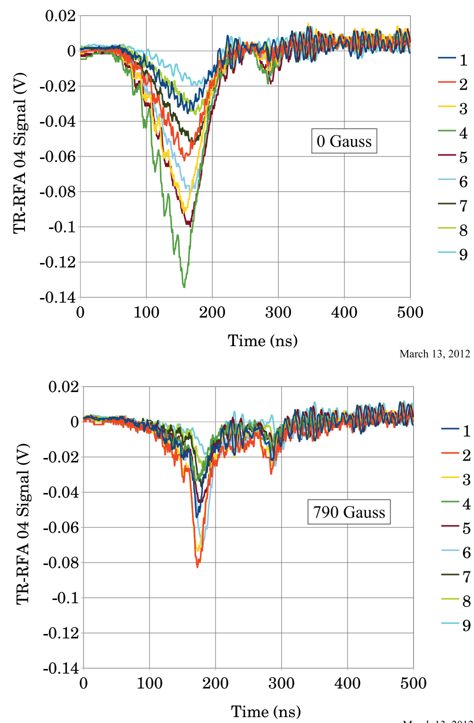

Figure 4: Signals from the nine collectors of the aluminum smooth wall chamber with 10 bunches of positrons at 8mA (1.3×10^{11} particles) per bunch and one witness bunch 112 ns after the train. The upper plot is with no dipole field; the lower plot is at 790 Gauss.

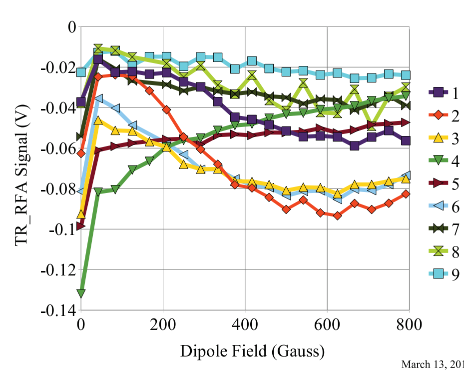

Figure 5: Under the same conditions as Fig. 4, the negative peak voltages from each collector are plotted over the range of magnetic fields from zero to 790 Gauss.

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FOUR CHAMBER ASSEMBLY

In August 2012, four test chambers were assembled and installed at CESRTA in order to test their (EC) mitigation performance. A TR-RFA was installed in each chamber. The chamber extrusions have two round cross sections, one smooth and the other with grooves at the top and bottom of the chamber as shown in Fig. 1.The grooves are intended as an EC mitigation technique in dipole magnets. Two chambers of each cross section were made, each about 66 cm long. One pair has a surface of bare aluminum and the other pair has a coating of TiN on the vacuum surface. They were assembled and installed with each chamber centered in a dipole of a four magnet chicane.

The construction of the chambers required particular care in machining the 270 holes of 1.7 mm diameter for the detector in the grooved chamber. To avoid burs on the inner surface of the grooves, tests were made with mounting wax and normal machining as well as Electrical Discharge Machining (EDM) fabrication of the holes. EDM was used for all of the chambers. The rows of holes were intentionally staggered so that the signal from each collector would be the average over the grooved surface beneath it.

Given the large beam induced signal seen in the prototypes, the depth to diameter ratio of the holes could have been changed to increase attenuation. The hole geometry was left unchanged in order to better compare the data from the original standard RFAs and the TR-RFAs to be installed at the same location.

Some preliminary data was taken shortly after installation. A 10 bunch positron beam at 5.3 GeV was injected into the storage ring to 60 mA total current. Data from the two grooved chambers without a magnetic field is shown in Fig. 6. As expected, the signal from the bare aluminum chamber is larger than that from the TiN coated chamber. Additional analysis is required to determine whether or not there is quantitative agreement with the model. The direct beam signal appears to generate ringing in the data that is similar to that of the prototype.

SUMMARY AND FUTURE WORK

Four Time Resolved Retarding Field Analyzers have been installed in test chambers at CESRTA. Electron cloud signals are measurable with short bunch trains and some interesting effects have been see in the data as a function of magnetic field.

The new TR-RFAs have also be connected to the original time averaging electronics and data has been taken in this configuration. A comparison of the two data taking methods is in progress.

The upcoming experimental run in late 2012 will offer an opportunity to do some systematic data taking. This will include using the retarding grid to obtain additional energy information. A good deal of work also needs to go into simulation of the beam-pipe geometries and the detectors, as has been done with the existing Retarding Field Analyzers and Shielded Pickups.

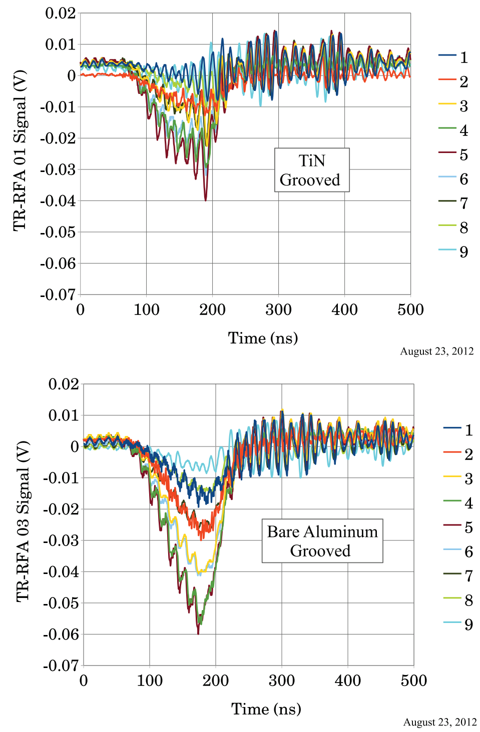

Figure 6: Signal from the nine collectors of grooved chambers with 10 bunches of positrons, 6mA (9.6×10^{10} particles) per bunch. The upper plot is from the TiN coated chamber; the lower plot is bare aluminum.

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