# DESIGN, IMPLEMENTATION AND FIRST RESULTS OF RETARDING FIELD ANALYZERS DEVELOPED FOR THE CESRTA PROGRAM*

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*Abstract*

A central component of the operation of the Cornell Electron Storage Ring as a Test Accelerator (CesrTA) for ILC Damping Rings R&D is the characterization of electron cloud growth in each of the principal vacuum chamber types in use in the storage ring. In order to facilitate measurements in chambers with tightly constrained external apertures, retarding field analyzers have been developed that can be deployed in regions with as little as 3mm of available aperture. We report on the design, fabrication, characterization and operation of devices that are presently deployed in CESR drift, dipole, and wiggler chambers.

## INTRODUCTION

In order to characterize the distribution of the electron cloud (EC) build-up around the Cornell Electron Storage Ring (CESR), retarding field analyzers (RFAs) are being deployed at multiple locations in the ring. Local EC measurements provided by these devices represent a core element of the CesrTA experimental program:

- They provide a baseline measurement of the EC densities and energy spectrum in each of the major vacuum chambers and field regions in CESR;
- By using segmented designs, each RFA provides detailed information about the transverse distribution of the EC in each vacuum chamber;
- In combination with non-local techniques, such as bunch-by-bunch tune measurements of long trains, the information obtained from these devices can be used to constrain the primary photoelectron yield and the secondary electron yield models which describe the overall development of the EC;
- Finally, when employed in vacuum chambers with EC mitigation, these devices directly measure the efficacy of various mitigation techniques being considered for the ILC Damping Rings.

## HARDWARE DESIGN

The RFAs we have designed for use in CESR are primarily intended for vacuum chambers where detector space is severely limited due to magnet apertures. Thus the design minimizes the thickness of the structure although this has performance implications for the device – in particular, the maximum retarding voltage will be limited to a few hundred volts and we expect somewhat degraded energy resolution. A self supporting 0.006 inch thick stainless steel with an etched bi-conical hole structure (0.007in diameter holes with a 0.01in pitch) was chosen for the grids while the electron collector pads were laid out on copper-clad kapton sheet using standard printed circuit board fabrication techniques. These layers can be supported with machined ceramic or PEEK structures. Fig. 1 shows a specific RFA structure that was used both for bench testing with an electron gun and for beam testing in CESR. Typically, the grid layers are vacuum-coated with a thin Au layer (several hundred nm) to reduce their secondary electron yield. Operating voltages are typically 20-100V on the collector and retarding voltages in the range of +100 to -300V.

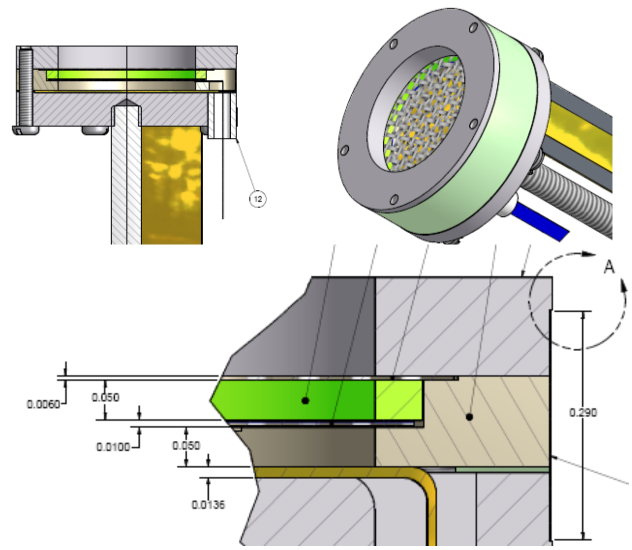


Figure 1: The basic retarding field analyzer structure for use in vacuum chambers with limited external aperture. Two variants of this test design have been employed. In the first variant (shown), two grids are employed in front of a collector made of copper-clad kapton. In the second variant, the front grid is replaced by a block of copper with a hole pattern of the same type as implemented in the walls of the CesrTA diagnostic wiggler vacuum chambers. In these designs, the layers are supported by a ceramic structure with an interlayer spacing of ~1mm.

A modular high voltage (HV) power supply and precision current monitoring system has been designed to support RFA measurements at multiple locations around CESR. A block diagram is shown in Fig. 2. Each HV supply contains two four-quadrant grid supplies and a single unipolar collector supply. The standard grid supply can operate from -500V to +200V and can provide -4.4mA to 2.4mA at 0V. The unipolar collector supply can operate from 0V to 200V and is rated for 50mA. A

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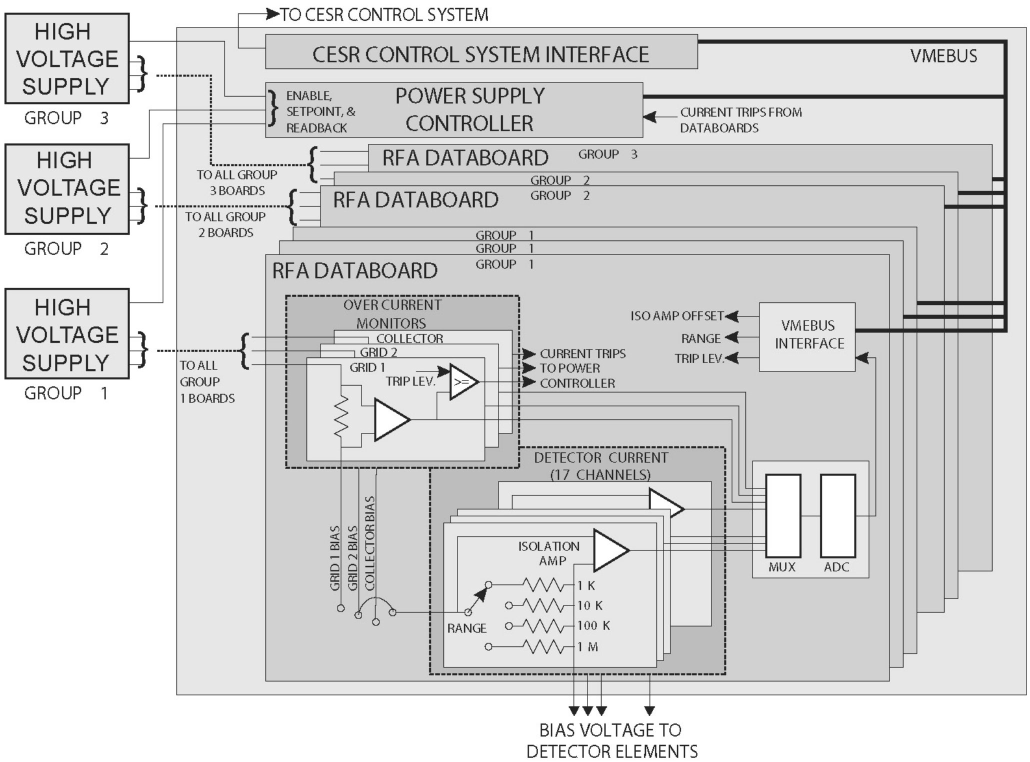


Figure 2: Schematic showing the high voltage power supply system and the RFA current monitor boards.

digital control loop is used to set and stabilize the output of the each supply with a feedback resolution of 60mV. The feedback is specially configured to enable high precision current measurements while the feedback loop is quiescent. Upon receipt of a voltage command, the HV control sets the voltage and allows it to stabilize. At that point, all feedback corrections are suspended for a 20 second data acquisition window. The controls for the two grid and single collector supplies in a full HV supply are configured to make this quiescent period simultaneous.

The RFA data boards distribute bias voltages to the detector elements (up to 17) and measure the current flow in each. The current is measured by an isolation amplifier looking at a series resistor (selectable as 1, 10, 100 or 1000kΩ) in the high side of the circuit with the output going to a 16-bit digitizer. The various resistors correspond to full scale ranges of 5000, 500, 50, and 5nA. The finest resolution is 0.15pA.

The readout system is in a 9U VMEbus crate with a custom P3 backplane that distributes bias voltages to the databoards. This backplane is divided into three segments, each with its own HV power supply. A common controller board controls all of the HV supplies and incorporates voltage and current trip capability. The entire crate is connected to the CESR control system through the local fieldbus. Data acquisition code running on the CESR control system is capable of running energy scans and continuous current monitoring by way of this communications path. Separate data acquisition servers operate for each of the crates deployed in CESR. Code to support central control of all servers for simultaneous scanning is currently being implemented.

## CALIBRATION STUDIES

Non-beam and beam-based checks of the new RFA design have been performed. Fig. 3 shows the results of a number of scans acquired with an electron gun. The RFA configuration which was tested used a front “grid” which was a slab of copper with holes corresponding to those in the vacuum chamber of a diagnostic wiggler[1]. Simulations which include the effects of secondary electron generation in the “vacuum chamber” holes, secondary generation on the surface of the grid, and a focusing effect of the grid holes when a retarding field is applied are shown overlaid with the data in each plot in Fig. 3. Overall, the simulations replicate all of the major features observed in the data including: the relatively higher collector efficiency than would be expected from the geometric transparency of the grids (Fig. 3 top plot); an excess of low energy electrons created in the holes which is observed as excess low energy current in both the retarding grid and the collectors (Fig. 3 middle and bottom plots); as well as the tendency of the net grid current to plummet or even switch signs due to secondary emission when retarding voltages are applied (bottom plot). Fig. 4 shows beam measurements which compare the performance of a segmented detector of the new design in a drift region with two adjacent APS-style RFAs[2]. The vacuum chamber ports were designed so that the outer and inner pairs of collectors in the segmented RFA would measure the same region as a corresponding RFA of the APS design. Overall the current response (top plot) and the energy response (bottom plot) of the devices show excellent agreement.

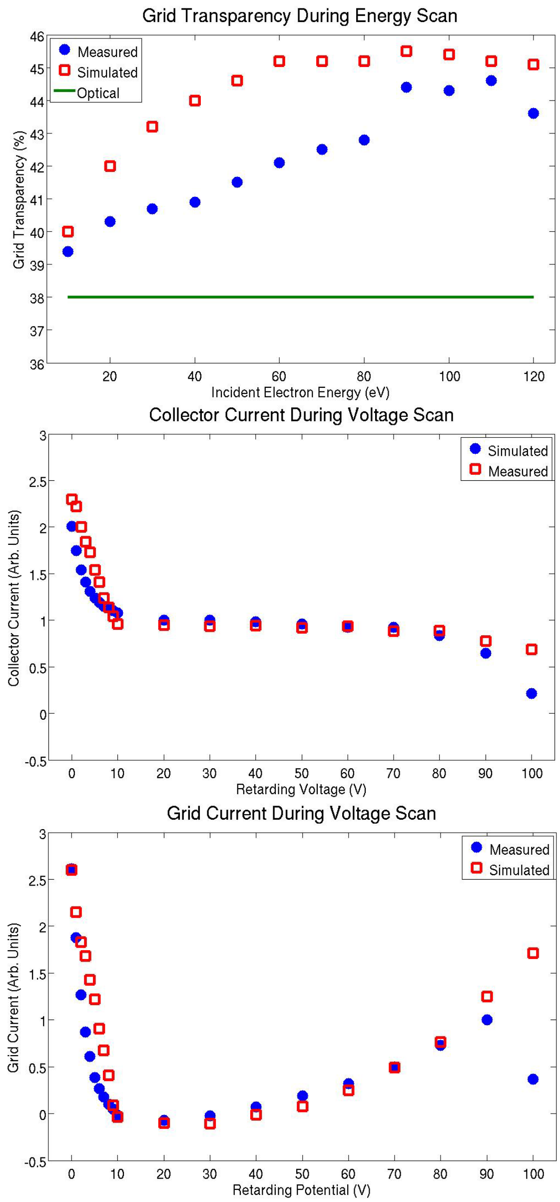


Figure 3: Plots showing electron gun studies of the performance of the thin RFA structure with a front plate with holes matching the wiggler vacuum chamber specifications. The top plot shows the fraction of electrons reaching the collector versus the energy of the incident electrons. The bottom pair of plots show the collector and grid currents observed during a retarding voltage scan with 110eV incident electrons.

## CONCLUSION

Overall, the thin RFA design appears to provide the necessary performance for application in CesrTA. Variants of the design have been deployed in drift, dipole and wiggler regions[1,3] and are providing useful data [4]. An important conclusion of our studies to date is that the detailed properties of the RFAs must be included in our physics simulations. This is a particularly important issue for RFAs deployed in high field magnets.

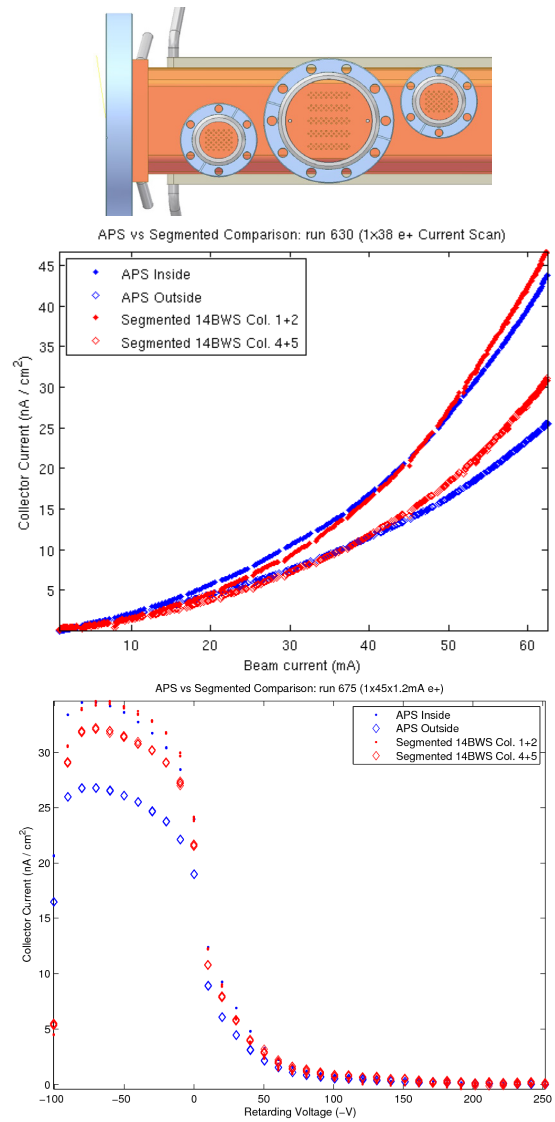


Figure 4: Beam comparisons of new segmented RFAs with APS-style structures. Top drawing shows the arrangement of a segmented RFA and 2 APS-style ports where the response of the 2 outer and 2 inner segments can be directly compared with the 2 APS RFAs. Middle plot compares the current response and the bottom plot compares the energy response of the detectors.

## REFERENCES


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