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Anticipated Signal Levels for the ESA and RPA

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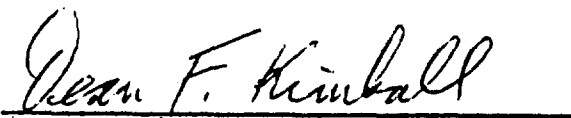
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"This technical report has been reviewed and is approved for publication"



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Introduction

The accelerator module is equipped with four electron guns and several detectors to monitor the electron beam produced by the guns. The guns will produce a nominal 3 keV, 40 ampere electron beam. For the beam to propagate, the return current must equal the beam current. There is no detailed model for the EXCEDE III return current, therefore, for these calculations the current is assumed to distribute itself isotropically and uniformly over the module. It is noted that recent data from tests on the accelerator module indicate that the return current may not be uniform. The accelerator module is 38 inches in diameter and 101.5 inches long. This corresponds to an average return current of 4.3×10^{-4} A/cm².

Two instruments are being provided by Visidyne to measure the current at the accelerator module. The two instruments are sensitive to different spectral regions of the backscattered electron distribution. The Electrostatic Analyzer (ESA) detects electrons having energies between 100 eV and 6000 eV; the Retarding Potential Analyzer (RPA) is sensitive to energies between zero and 100 eV. A schematic of the location of the ESA and RPA on the accelerator module is shown in Figure 1.

Secondary Electron Distribution

The expression for the detected current is given below:

$$I_{det} = \iiint F(\Theta, \phi, E) dA d\Omega dE \left(\frac{\text{electrons}}{\text{sec}} \right)$$

where $F(\Theta, \phi, E)$ is the flux. The detected current is the electron flux integrated over the electron energy, the detector area, and its solid angle. The return current is assumed to be isotropic and therefore the flux $F(\Theta, \phi, E)$ at the payload surface is simply proportional to $\cos\Theta$. The return current over the entire module is

$$I_{tot} = \iiint N(E) A_{mod} \cos\Theta \sin\Theta d\Theta d\phi dE$$

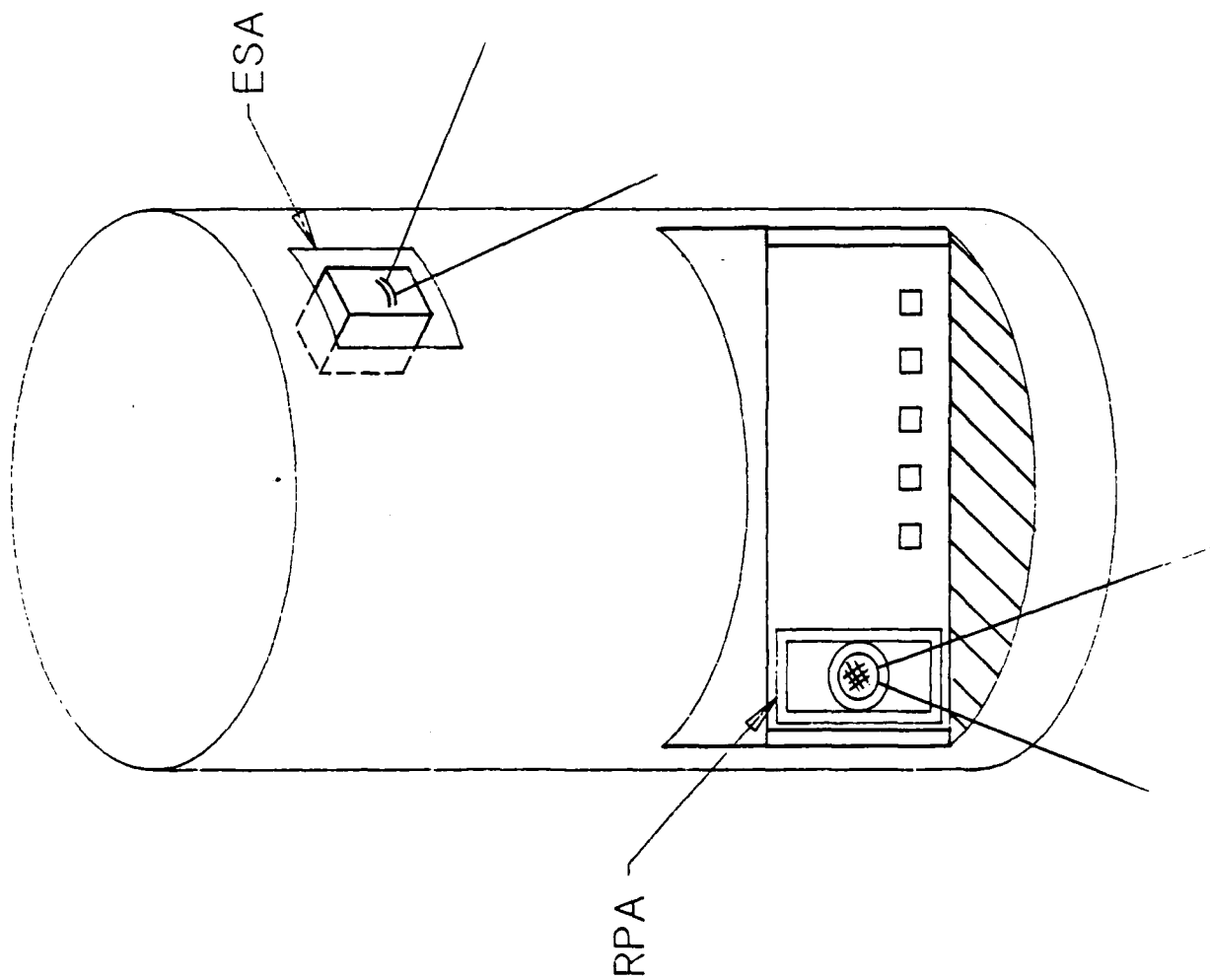


Figure 1. Schematic drawing showing the positions of the ESA and the RPA on the payload.

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$$\int \frac{N(E) A_{\text{mod}} \pi dE}{I_{\text{TOT}}} = \int n(E) dE$$
$$N(E) = \frac{n(E) I_{TOT}}{A_{mod} \pi}$$

The energy distribution curve used for the ESA and RPA calculations (Figure 2), is derived from the Banks et al. calculation for the upward flux generated by 10 keV auroral electrons. To obtain the spectra shown in Figure 2 the low energy peak on the Bar's et al results was left at 4 eV and the high energy peak was moved to 3 keV. The remaining features of the distribution were scaled in proportion to the 10 keV data.

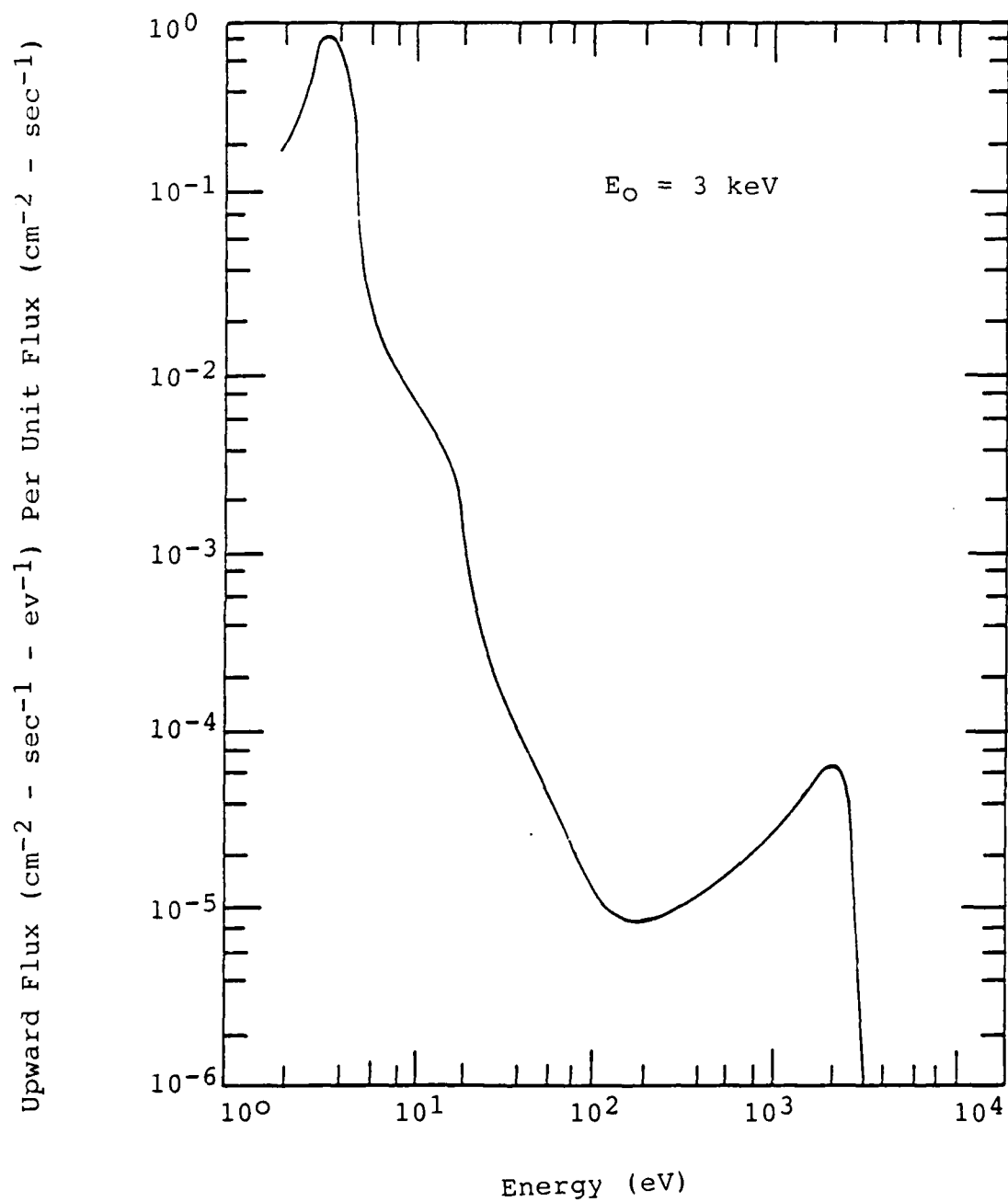


Figure 2. Secondary electron distribution used in Calculation.

Electrostatic Analyzer

The Electrostatic Analyzer is a device designed to measure the number of electrons having energies between 100 and 6000 eV. A block diagram of the instrument and the associated electronics is shown in Figure 3. Two spherical plates having a radial electric field between them direct incident electrons having the correct energy onto a Faraday cup. The energy spectrum of the electrons is measured by changing the voltage on the inner plate to change the radial electric field. Table 1 lists the specifications for the ESA.

Table 1
ESA Parameters

Energy	100 eV - 6 keV
Sensitivity	10^{-9} to 10^{-3} A
Energy Resolution	12%
FOV	$6.4^\circ \times 16^\circ$
AΩ	4.6×10^{-2} cm ² -sr
Sweep Period	1 Second
Sweep Time Constant	110 msec

The signal is calculated by the formula

$$\Delta I(E)_{\text{ESA}} = (n(E)/\pi) (I_{\text{tot}}/A_{\text{mod}}) (A\Omega)_{\text{ESA}} 0.12 E$$

where $n(E)/\pi$ is the energy distribution of the flux on the module and $I_{\text{tot}}/A_{\text{mod}}$ is the beam return current uniformly distributed over the accelerator module. The anticipated currents measured at the Faraday cup of the ESA are listed in Table 2 and plotted in Figure 4. The ESA is designed for operation between 6 keV and 100 eV. However, the sweep will actually cover the range from 6 keV to 1 eV. The predicted currents over the range from 6 keV to 100 eV vary from less than 10^{-9} A which corresponds to the minimum near 100 eV to a maximum of approximately 3×10^{-7} A near 3 keV. The dynamic range of the instrument is 10^{-9} to 10^{-3} A.

DUAL GUARD

GRID

e

DEFLECTION
PLATES

-5V

FARADAY
CUP

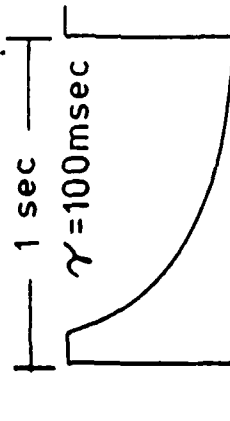
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AMP



EXPONENTIAL
SWEEP
GENERATOR

1KHz
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TRANSFORMER

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ESA SCHEMATIC

SWEEP
MONITOR
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Figure 3.

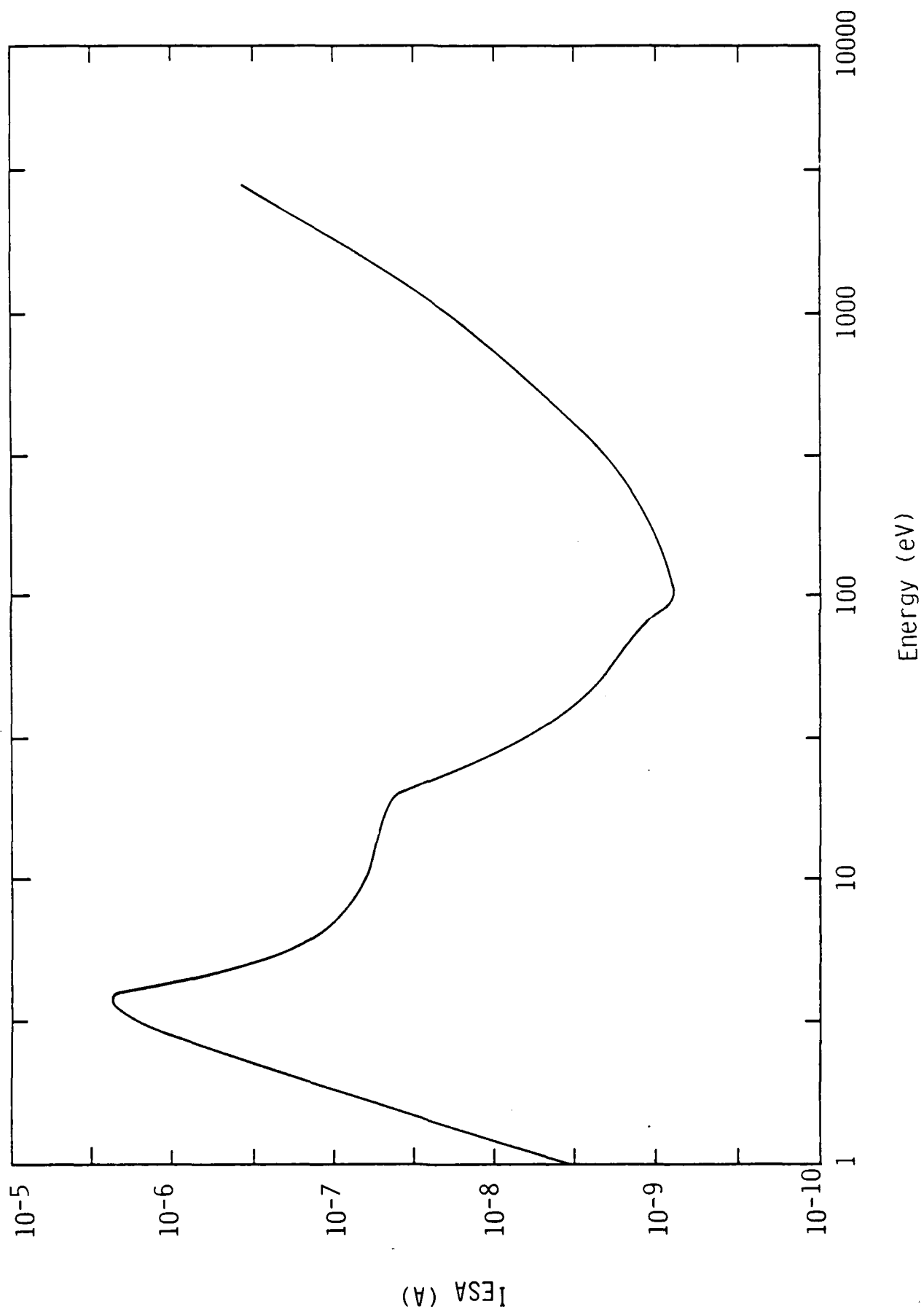


Figure 4. Signal levels for ESA.

Table 2
ESA Signal Levels

<u>Energy (eV)</u>	<u>I_{ESA} (A)</u>
1	3.55×10^{-9}
2	1.51×10^{-7}
4	2.42×10^{-6}
6	1.36×10^{-7}
8	9.08×10^{-8}
10	6.06×10^{-8}
20	4.55×10^{-8}
40	3.03×10^{-9}
60	1.82×10^{-9}
80	1.21×10^{-9}
100	7.59×10^{-10}
200	1.07×10^{-9}
400	3.02×10^{-9}
600	5.90×10^{-9}
800	1.15×10^{-8}
1000	1.66×10^{-8}
2000	1.21×10^{-7}
3000	3.87×10^{-7}

The ESA can be adversely affected by the return current in two ways. First, the return current not passed by the analyzer will be collected on the analyzer plates and, if this current is sufficiently large, it could load down the analyzer plate power supply. A second possible problem is that if the current passed by the analyzer is sufficiently large, the power supply for the Faraday Cup that measures the signal could be loaded down.

The entrance area of the ESA is 1.5 cm^2 , which corresponds to an upper limit on the return current of 6.4×10^{-4} at the ESA entrance aperture. This is also the maximum current that will be collected on the Faraday cup. The ESA is designed so that current which does not pass between the plates is collected on the plates. The voltage applied to the inner plate and the energy of the return beam will determine where the return current is collected. Since the outer plate is at ground, the ESA operation should be unaffected by the return current

collected on the outer plate. The inner plate has an exponentially declining voltage, which starts at 600 volts and has a time constant of 110 msec. The power supply for the inner plate is designed to provide 10^{-2} A. A grounded shield was placed next to the inner plate to limit the current collected on the exterior of the inner plate. The area of the exterior is approximately 4 cm^2 which corresponds to a current of 1.7×10^{-3} A.

Retarding Potential Analyzer

The retarding potential analyzer (RPA) is a Faraday Cup used to measure electrons with energies between zero and 100 eV. A drawing of the instrument is shown in Figure 5. The device is able to provide measurements of different energy electrons by changing the potential on a retarding grid. This grid repels electrons having energy less than the retarding potential. In addition, the Faraday cup is maintained at a potential of +20 V to collect any secondary electrons created inside the cup.

The RPA is sensitive to measured currents between 10^{-9} and 5×10^{-2} A. This range is covered by a linear amplifier (5×10^{-4} to 5×10^{-2} A), and a logarithmic amplifier (10^{-9} A to 10^{-3} A). Table 3 lists specifications for the RPA.

Table 3
Retarding Potential Analyzer Specifications

Sensitivity	10^{-9} A to 5×10^{-2} A
Area	0.32 cm^2
Field-of-View	87°
A Ω	$0.552 \text{ cm}^2 - \text{sr}$

The predicted signal levels are calculated below. As the voltage on the grid is swept, the measured current is the sum of all electrons having energies greater than the grid voltage. The formula used to calculate the measured current is

$$I(E_o)_{RPA} = \int_{E_o}^{\infty} n(E)/\pi (A\Omega)_{RPA} (I_{TOT}/A_{mod}) \epsilon_{grid} dE$$

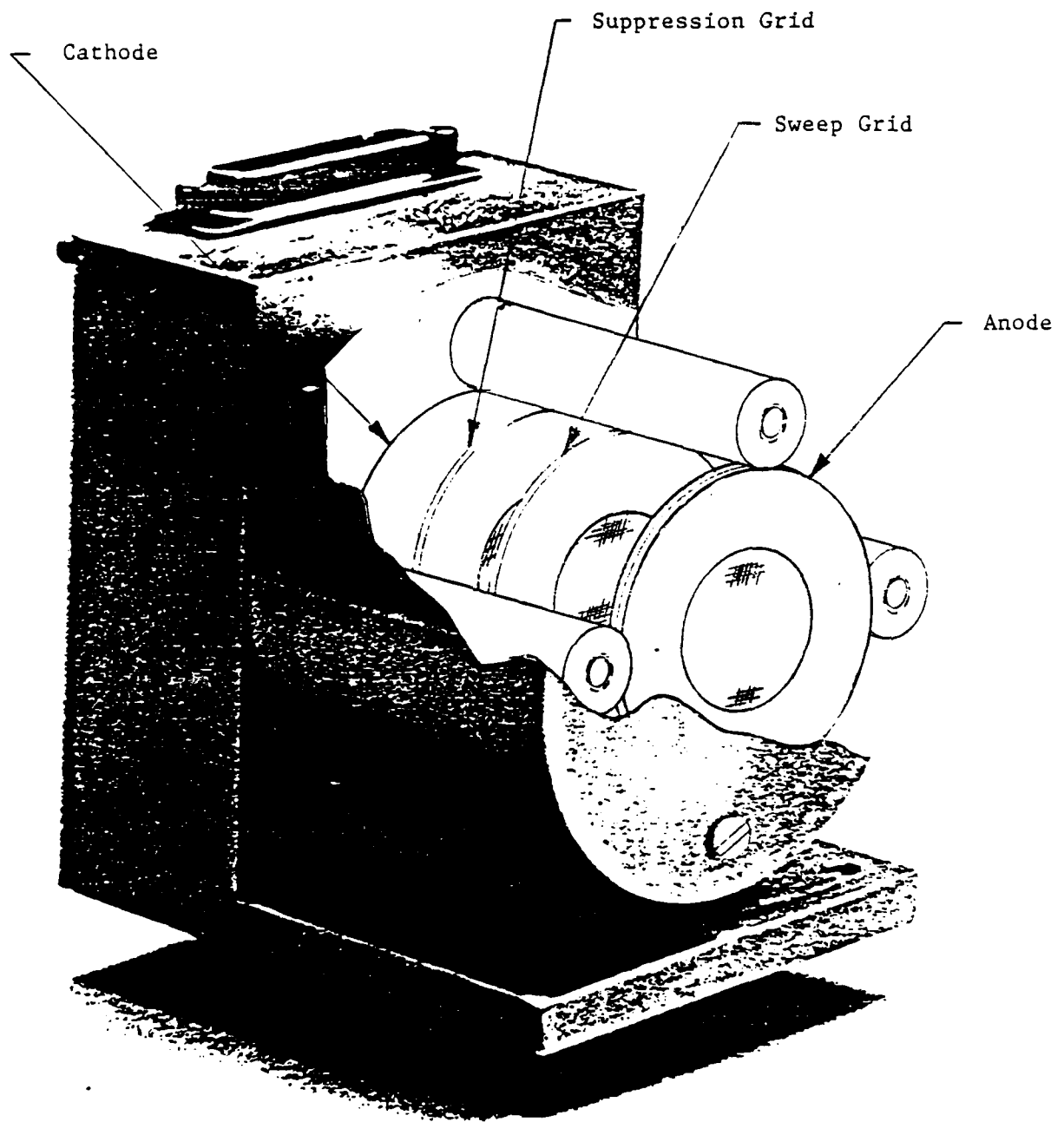


Figure 5. Schematic drawing of RPA.

where

$$n(E) = N(E) A_{\text{mod}} \pi / I_{\text{TOT}}$$

ΔE = Energy resolution,

I_{ret} = Return current (= 40A)

A_{mod} = Surface area of the accelerator module

ϵ_{grid} = Transmission of the grids

The results of this calculation are shown in Figure 6 and listed in Table 4. The predicted current ranges from 10^{-4} A at the lower energies to 10^{-5} A near 100 eV.

The results listed below are calculated with a field of view of 87 degrees. A smaller field of view will decrease the signal levels but improve the energy resolution. The smaller field of view is presently being investigated in the laboratory and Table 4 represents upper limits.

Table 4
RPA Signal Levels

<u>Energy (eV)</u>	<u>I_{RPA} (A)</u>
1	1.2×10^{-4}
2	1.1×10^{-4}
4	2.8×10^{-5}
6	1.8×10^{-5}
8	1.6×10^{-5}
10	1.5×10^{-5}
15	1.3×10^{-5}
20	1.2×10^{-5}
40	1.1×10^{-5}
60	1.1×10^{-5}
80	1.1×10^{-5}
100	1.1×10^{-5}

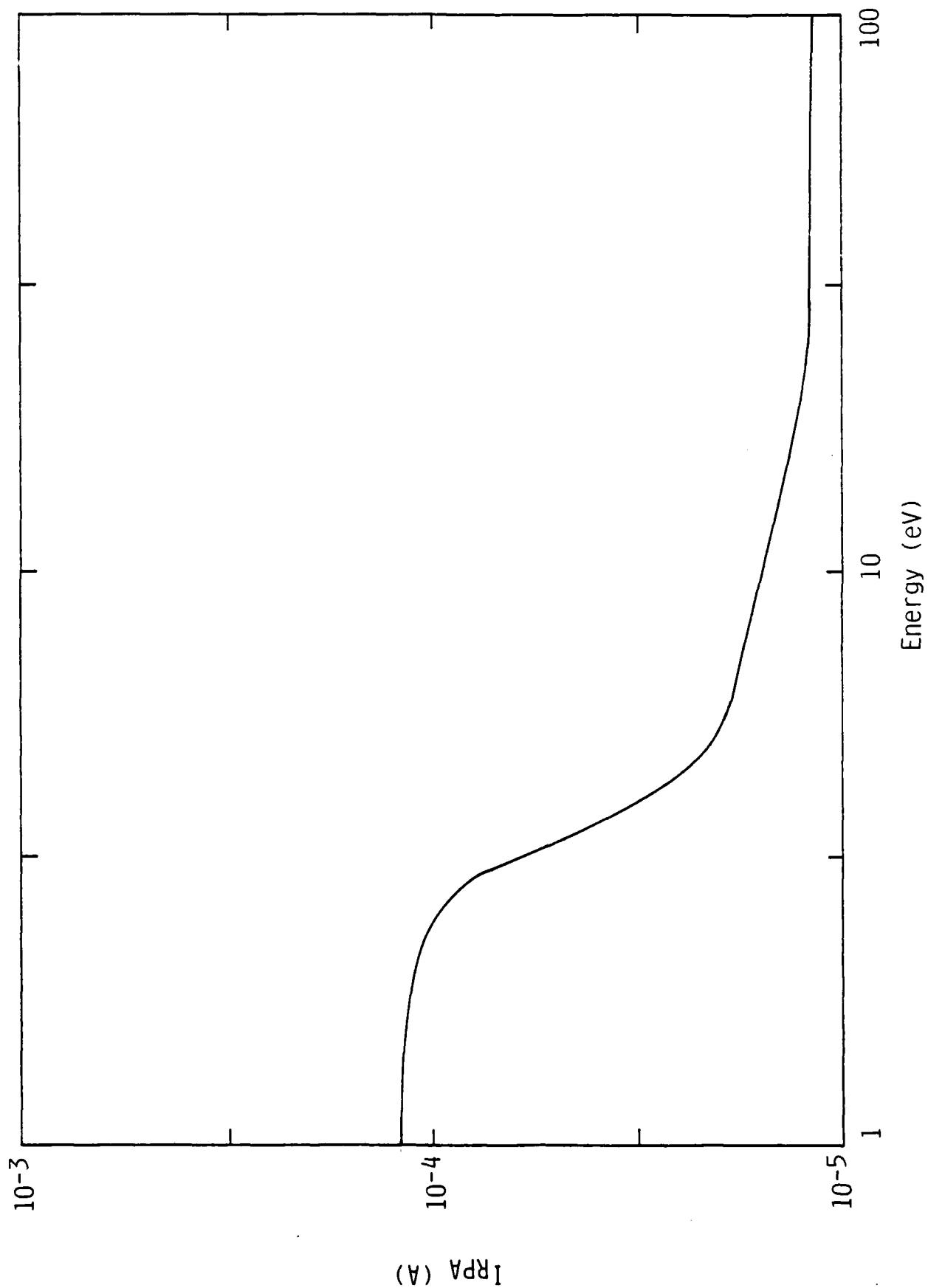


Figure 6. Signal levels for RPA.

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1. Banks, P.M., C.R. Chappell, A.E. Nagy, "A New Model for the Interaction of Auroral Electrons with the Atmosphere: Spectral Degradation, Backscatter, Optical Emission, and Ionization", J. Geophys. Res., Vol. 79, 1459 (1974).