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A UNIQUE ION GUN TO BE USED IN THE STUDY OF ION DETECTORS

By Henry A. Lackner, PhD and George M. Wood, Jr.

NASA Langley Research Center
Langley Station, Hampton, Va.

Presented at the Fifteenth Annual Conference
on Mass Spectrometry and Allied Topics

Denver, Colorado
May 14-19, 1967

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INTRODUCTION

The evident trend in analytical applications today is away from large, complex, general purpose mass spectrometers towards smaller, less sophisticated instruments designed for a particular set of analytical parameters. This is particularly true in space directed instrumentation, and is becoming more so in other fields.

Because of this trend, the Vacuum Measurements Section at the Langley Research Center has for some time been investigating and supporting the development of spectrometer components. The purpose of this investigation is three-fold: first - to increase our knowledge of the operational mechanics of source, mass separator, and detector; second - to extend the capabilities of existing sources and detectors to their absolute limit; third - and probably most important - to permit the design of the minimal instrumentation providing adequate resolution and sensitivity demanded by a task, thereby resulting in maximum savings in time and cost.

The study of ion detectors - much of which has been done under a NASA grant to Dr. F. A. White at R. P. I. in Troy, N. Y. - is intended to extend the range of measurement to 10^{-19} amperes with a high degree of certainty, and to establish certain other detector characteristics. In order to examine these characteristics with some precision, the use of an unperturbed ion beam is necessary, as is a method of indirectly measuring the ion current prior to impingement on the collector. It was for these reasons that the proto-type ion detector described in this paper was developed.

THEORY OF OPERATION

A positive ion beam passing through an electrically isolated detector tube is periodically interrupted for a duration of several microseconds (Fig. 1). This is the equivalent of superimposing a pulsed negative beam (hereafter referred to as the "Charge-slug") with the same magnitude of charge density and current as the positive beam. If the "charge-slug" is longer than the detector tube, we have a good approximation to cylindrical symmetry and may assume that all of the flux due to the charge within the tube is intercepted by the tube. In this case, the combination of "charge-slug" and tube form a capacitor in series with the input capacitance of the preamplifier so that the charge contained in the tube appears across that input capacitance. Since the RC constant of the input is large (80 μsec) in comparison with the pulse duration, (2 - 9 μsec) the output voltage is given by

(1) $V = q/c$ where q is the charge and c is the input capacitance. The charge per unit length, is thus

(2) $\lambda = q/L$ where L is the length of the detector tube; and the ion beam current is then $i = \lambda$ times ion velocity μ or, by substitution

(3) $i = \lambda, \quad \mu = \frac{q}{L}, \quad \mu = \frac{cV\mu}{L}.$

This detection scheme thus permits nearly simultaneous measurement of ion beam current and response of the collector to the beam. Further, if the detector is far from the nearest beam interception point, it should respond only to changes in the beam itself, and not to backscattered ions or emitted electrons from the collector.

EXPERIMENTAL APPARATUS [redacted]

The schematic diagram of the apparatus is as shown (Fig. 2). The source is essentially a duo-plasmatron which has been modified by increasing the distance between the intermediate electrode and anode; and by re-positioning the filament nearer the opening in the conical portion of the intermediate electrode. This permits operation at lower

*Old Dominion College, Norfolk, Virginia,
ASEE - Summer Institute Fellow and Consultant to NASA.

pressures than normal, and prolongs filament life by reducing arc current. Gas pressure in the source is controlled by a leak valve which is opened until the vacuum system pressure is about 5×10^{-7} torr. Source pressure has not been directly measured, but is calculated to be about 1×10^{-4} torr for a beam current of 5×10^{-8} amperes; the pressure in the flight tube is about 1×10^{-5} torr.

The ions are accelerated in the gap between the source aperture and the grounded extraction electrode. It is then focused by a single cylindrical electrode, which, in common with the vacuum system wall forms an Einzel lens. The focusing voltage is adjusted to provide maximum indicated current on the final collector. The beam passes through a pair of deflection plates, an aperture to effect a sharp cutoff, and into the detector. A Hewlett Packard 212A pulse generator provides square pulses up to 100V to deflect the beam away from the aperture at repetition rates up to 5 kilocycles per second. The detector therefore sees a periodically interrupted beam.

The detector is a section of stainless steel tubing 2.54 cm in diameter and 12.2 cm long with Varian flanges welded on each end. It is electrically insulated from the rest of the system by 3 cm thick circular blocks of teflon; and is entirely contained in a grounded metal box which provides shielding against stray noise. Output signals are amplified by a simple triode and cathode follower circuit; and are displayed on a Tehtronics 545A Oscilloscope. The final ion collector used for this test was a flat copper disc connected by a feedthrough to a Keithly micro-micro ammeter; with a means of repelling secondary electron emission.

EXPERIMENTAL RESULTS

The next three figures show pulses produced by the detector for several deflection pulse durations, the first of which is taken at 2μ seconds. In each case the oscilloscope is set at 20 MV/cm vertical deflection and a scan of 5 μsec/cm. The electrometer reading varied from 4.3 to 4.5×10^{-8} amperes during each run, with nitrogen used as the pressurizing gas.

At an accelerating voltage of 550 volts, the velocity of positive nitrogen ions is about 6.5 cm/μsec, so the pulse length in this figure is approaching the detector length. The induced voltage therefore rises to its maximum value and immediately begins to decay as the pulse leaves the detector. Figure 4 shows the peak obtained at 5 μsec. Increasing the pulse duration results in no amplitude increase but produces a flattening of the observed voltage peak, as becomes more apparent in the figure 5 taken at a pulse repetition rate of 9 μsec.

In these cases, induced potential increases as the "charge-slug" enters the tube and then remains relatively constant until the trailing edge of the slug enters, thus decreasing the total charge in the tube. Beam current was calculated from pulse amplitude to be in the order of 3×10^{-8} amperes. The slight increase noticed across maximum peak height has not been fully explained. However, it probably occurs because the detector tube is relatively short, and therefore the assumption of cylindrical symmetry is not completely satisfied; because of limitations in pre-amplifier response; and possibly because not all of the electron backscatter from the collector is surpressed.

The apparatus described here was assembled for the purpose of demonstrating the feasibility of the detector scheme, and so was constructed from components on hand - sections of tubing connected by Varian flanges, a bellows to allow alignment of the ion source, etc. The resulting deviations from the required good geometry undoubtedly cause some distortion and limit the accuracy to about 10 percent.

In conclusion, the detector method was tested with ion beam energies to 2000 V to simulate mass spec conditions with good results. The system is now being re-designed as a 3 piece instrument to include a 36.6 cm detector, improved electronics, and an ion source capable of operation at lower pressures.

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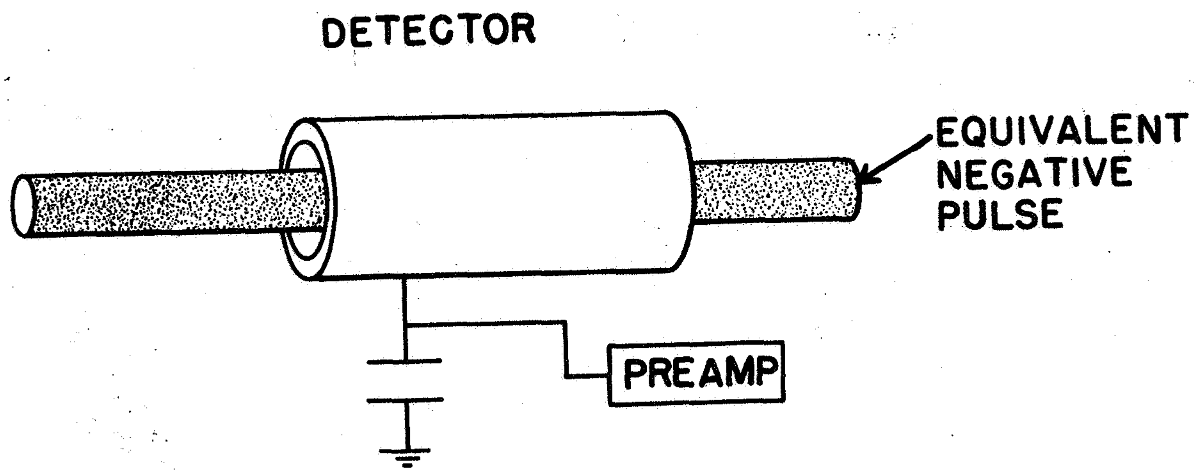

(1) $V = \frac{q}{c}$

(2) $\lambda = \frac{q}{L}$

(3) $i = \lambda\mu = \frac{q}{L}\mu = \frac{cv\mu}{L}$

Figure 1

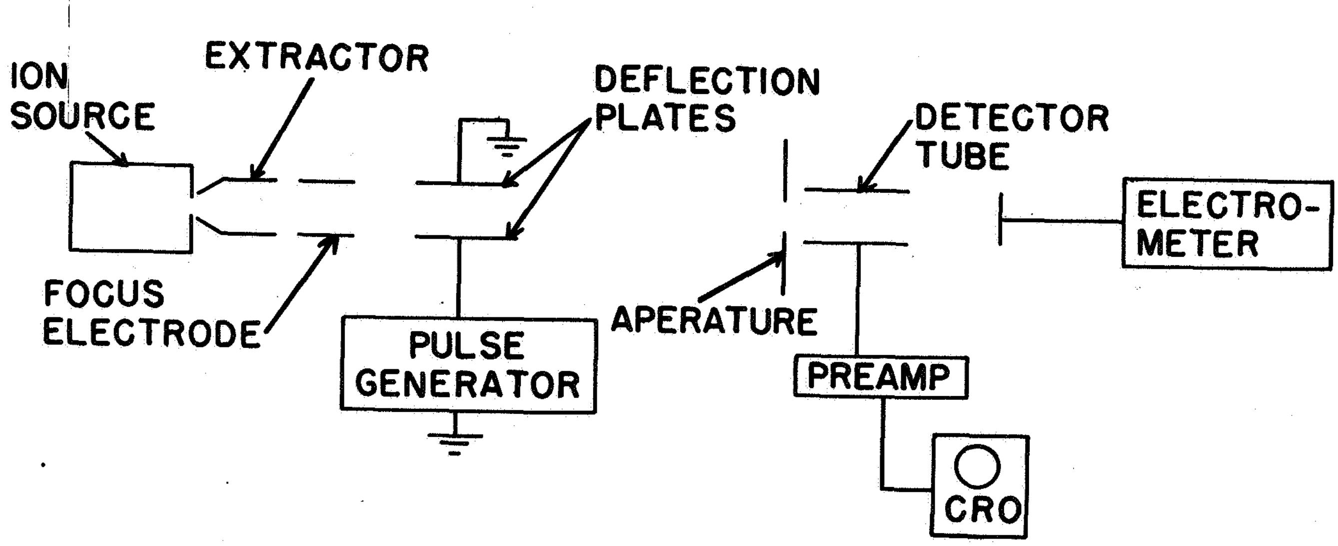

Figure 2

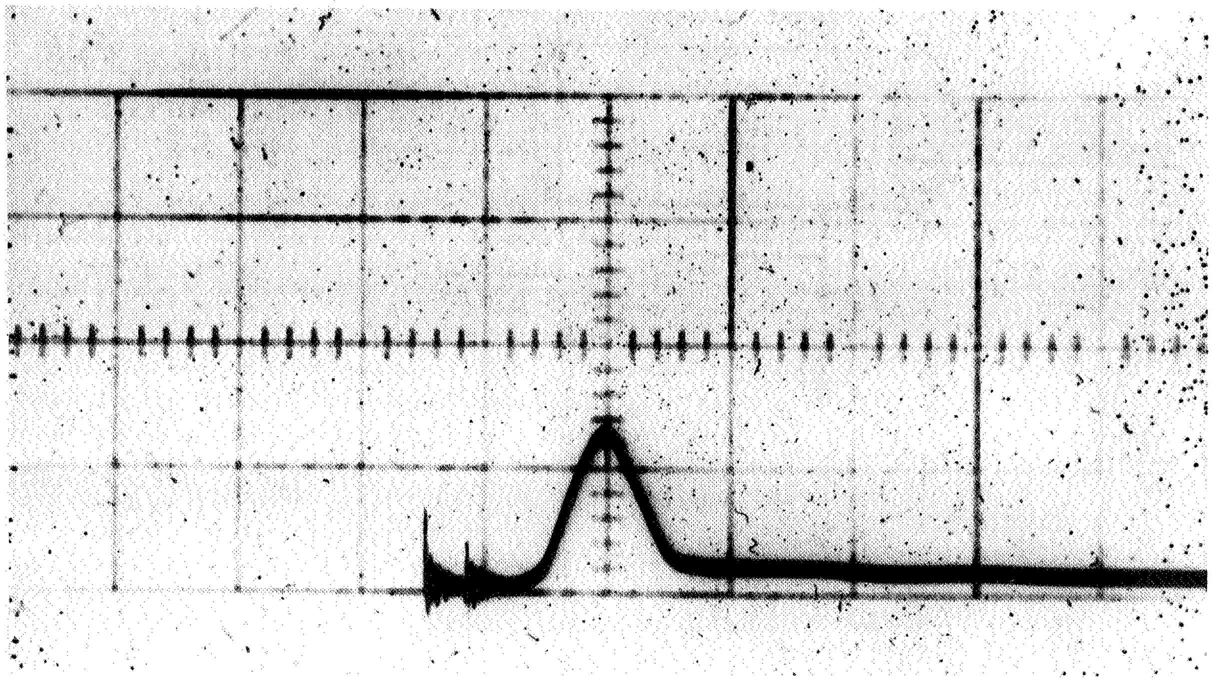

Figure 3

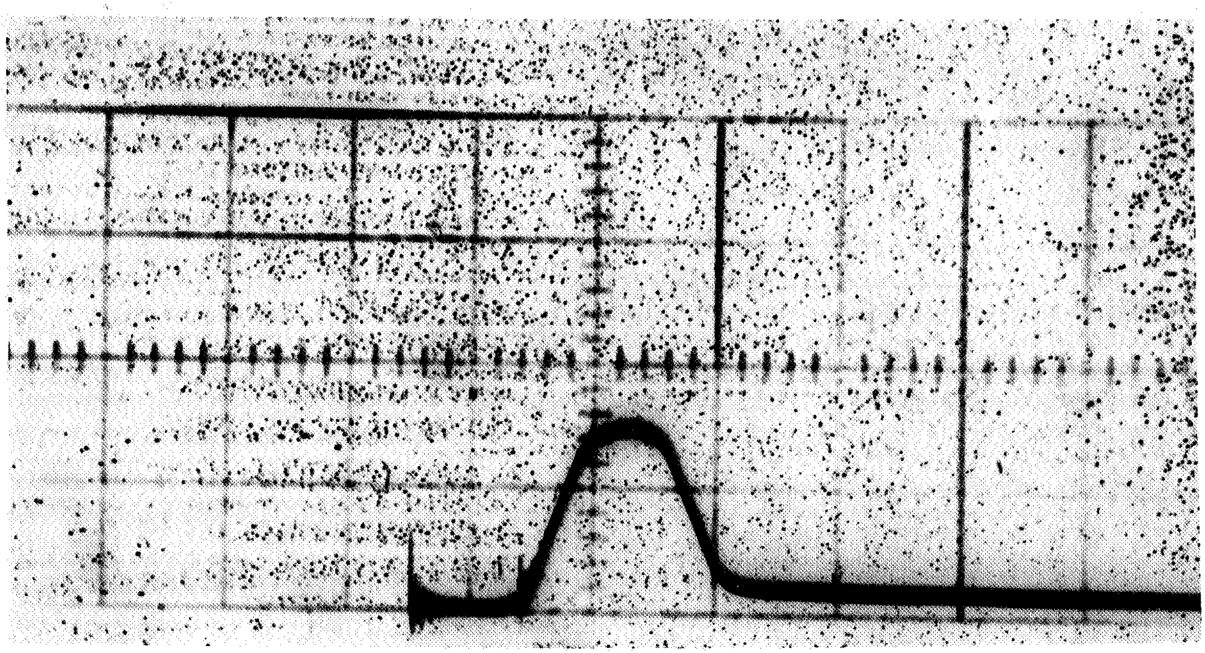

Figure 4

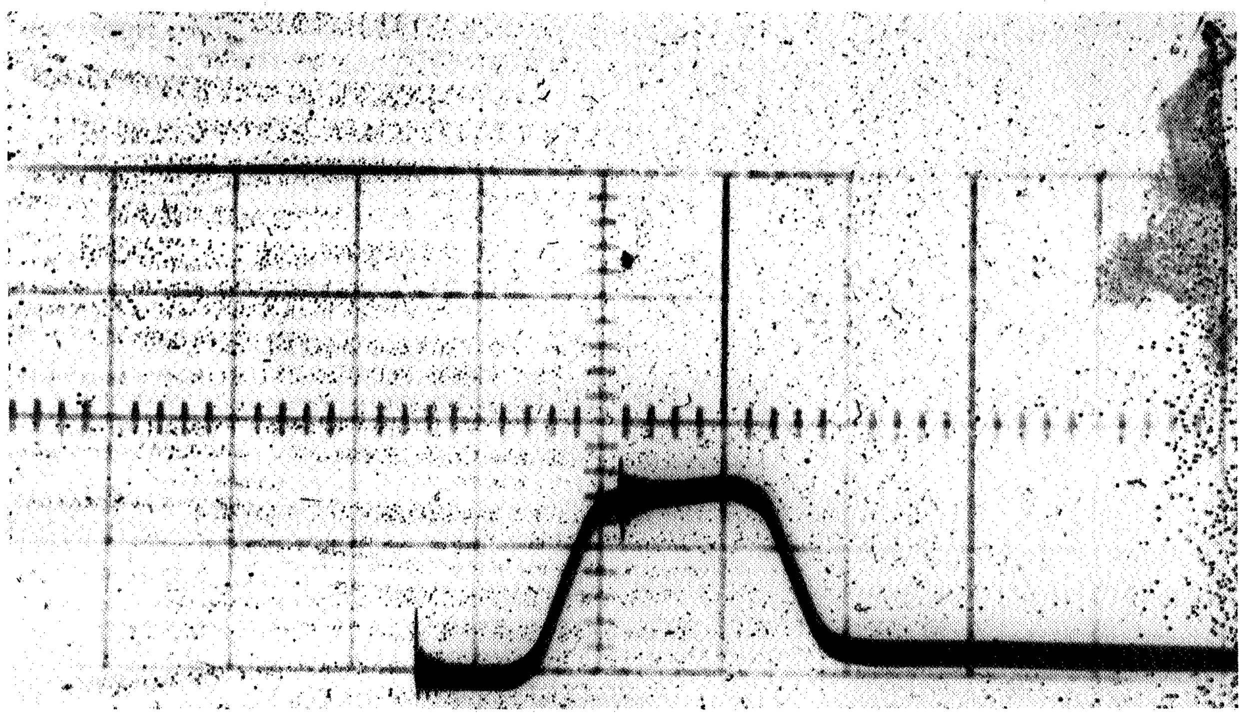

Figure 5