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A MULTICHANNEL SPECTROMETER
FOR THE ANALYSIS OF PULSED ION SOURCES

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ABSTRACT

A 180-deg mass spectrometer has been constructed for the analysis of pulsed ion sources, chiefly of the occluded-gas type. A complete ion spectrum can be obtained in five pulses of the source. The ions are collected in 94 equally spaced cups. Each of these cups is supported by a ceramic feedthrough insulator. Outside the vacuum tank each insulator is connected to a capacitor, one side of which is grounded. An electrical pickup progressively samples the potentials across the 94 capacitors. The pickup is connected to an electrometer whose output is fed into a recorder. Resultant spectra exhibit better resolution than a fixed-orbit spectrometer previously used.

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Introduction

A spectrometer has been developed for the analysis of pulsed ion sources, principally of the occluded-gas type. A previous spectrometer[1] for occluded-gas sources was designed to have a fixed orbit in a wedge-shaped magnetic field of variable intensity. With this instrument about 1000 shots from the ion source were required to record all peaks from H^+ to Ti^+. However, in occluded-gas sources of the evaporated-film type,[2] such a method of analysis is unsatisfactory, since 1000 shots is comparable to the life of the source. The new spectrometer accumulates a complete spectrum in five shots from the source, and incorporates improved resolution and transmission properties. The new instrument employs 180-deg magnetic focusing, and a 94-channel beam-collector system. The magnetic field is supplied by a C magnet with rectangular pole pieces measuring 13×24 in. and having a 2.5-in. gap.

Design

It was expected that readout for the 94 channels would probably consume several minutes, and therefore, that the time constant for leakage of a collector capacitor would have to be large compared with this interval. An electrometer with an input impedance of 10^{15} ohms was selected as the capacitor voltage-sensing device. A collector capacitor of 1000 pF at the input of such an instrument provides a time constant of 10^6 seconds. Various types of capacitors were tested for leakage by charging each to 100 mV, and then monitoring the time dependence of the stored charge by means of the electrometer. The only type of capacitor tested that would retain more than 99% of its original charge after a period of 3 min, and still not be so physically large as to become

unwieldy, was the silver-mica type; and it was therefore designated as the collector capacitor. The capacitors were matched to within 1% by charging a master capacitor to a given voltage and then placing it across the capacitor to be tested. Since the master is also 1000 pF, the voltage across the pair reduces to half the original voltage. Any capacitor not within 1% was rejected.

The collector cups are fastened mechanically to the vacuum tank, but are electrically insulated from it. The insulators that support these cups must have a high surface and volume resitivity, and must not become voltage sources during the operation. Many types of insulators were tested, and the one found to be most acceptable was Alite Number D-187 made by the Alite Division of U. S. Stoneware Corporation. Each collector cup was isolated from the adjoining cup by means of a grounded electrostatic shield plane between them. The collector cups have a vertical height of 3/4 in., and the ratio of collector area to total area is 0.50.

The original intent was to connect each of the collector cups to the electrometer by means of a rotary switch. Many such switches were tested, but it was found that the resistance between contacts was low enough to cause leakage between adjacent capacitors. All attempts to build a rotary switch failed, as it was not possible to find a dielectric material both suitable for mounting contacts, and possessing a very high resistivity. The rotary switch was abandoned, and a device was designed incorporating the vacuum-chamber feed-through insulators into a switch. Such a device has proved successful, and consists of a trolley that slides along two stainless steel rails, with a pickup supported from the trolley by two insulators of the same type as is used to support the collector cups. A simple escapement mechanism, similar to that used

to advance the carriage on a typewriter, allows the trolley to advance one step each time a printing device on the recorder supplies a 45-V impulse to a rotary solenoid. The trolley pickup is connected electrically to the electrometer, and, between each step, is discharged to ground. This is done to keep any residual charge on the coaxial cable leading to the electrometer from altering the charge on the next capacitor to be monitored. A schematic diagram of the circuitry is shown in fig. 1, and photographs of the system are shown in figs. 2 and 3.

The ion source is placed in a demountable-type assembly designed to facilitate rapid replacement of sources. A cylindrical shield surrounds the source. A fine-mesh wire screen over the shield opening has been found necessary to prevent breakdowns from occurring when the source is fired. A 2-in. stainless steel disk, spaced 3/4 in. from the source shield, serves to define the accelerating gap. An identical disk is situated 1.5 in. behind the first disk. In each of these has been milled a 1/8 × 3/8-in. vertical slot in order to collimate the beam. Guiding the collimated beam through the fringing magnetic field, a distance of about 6 in., and through a 1-in. opening into the vacuum chamber proved to be an unanticipated problem. The fringing field caused the lighter ions to be steered into the walls of the brass pipe used to guide them into the spectrometer chamber. The brass pipe and flange were replaced by mild steel, and the effect of the fringing field was satisfactorily eliminated.

It was desired to have a less than 1% drop in the acceleration voltage when the source delivered a beam of 5 A for 5 μsec. A 0.05-μF capacitor rated at 75 kV was placed across the "accel power supply," and this accomplished the required regulation. The source power supply, shaping network, and trigger generator must be operated at the accel

potential; hence, this equipment was isolated from ground by means of a 75-kV isolation power transformer. The spectrometer as well as all of the associated electronics was placed in a wire screen cage and electrically interlocked for personnel safety.

Results

A typical spectrum from an evaporated-film occluded-gas ion source was traced from the chart recorder, and is shown in fig. 4. Heavy ions, chiefly Ti^{+} and Ti^{++}, typically account for about 2/3 of the ion beam. The resolution is seen to be considerably superior to that of the earlier spectrometer.[1] By means of such spectra, variation of the ion composition as a function of such parameters as source current and source geometry has been studied.

An instrumental effect which has also been examined concerns the possibility of spectral distortion due to vertical defocusing which is dependent on the length of orbit. To obtain quantitative information, several spectra were obtained in which the magnetic field was progressively reduced so that the hydrogen ions traversed progressively larger orbits. It was found that the area under the peak remains substantially independent of orbit size so long as the orbit remains inside the fringing field.

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References

1. J. D. Gow and H. C. Pollock, Rev. Sci. Instr. 31 (1960) 235.
2. K. W. Ehlers, J. D. Gow, L. Ruby, and J. M. Wilcox, Rev. Sci. Instr. 29 (1958) 614.

Captions

Fig. 1. Spectrometer schematic.

Fig. 2. Spectrometer assembly and data readout system.

Fig. 3. Ion-source spectrum: five shots.

Fig. 4. Close-up of spectrometer vacuum chamber.

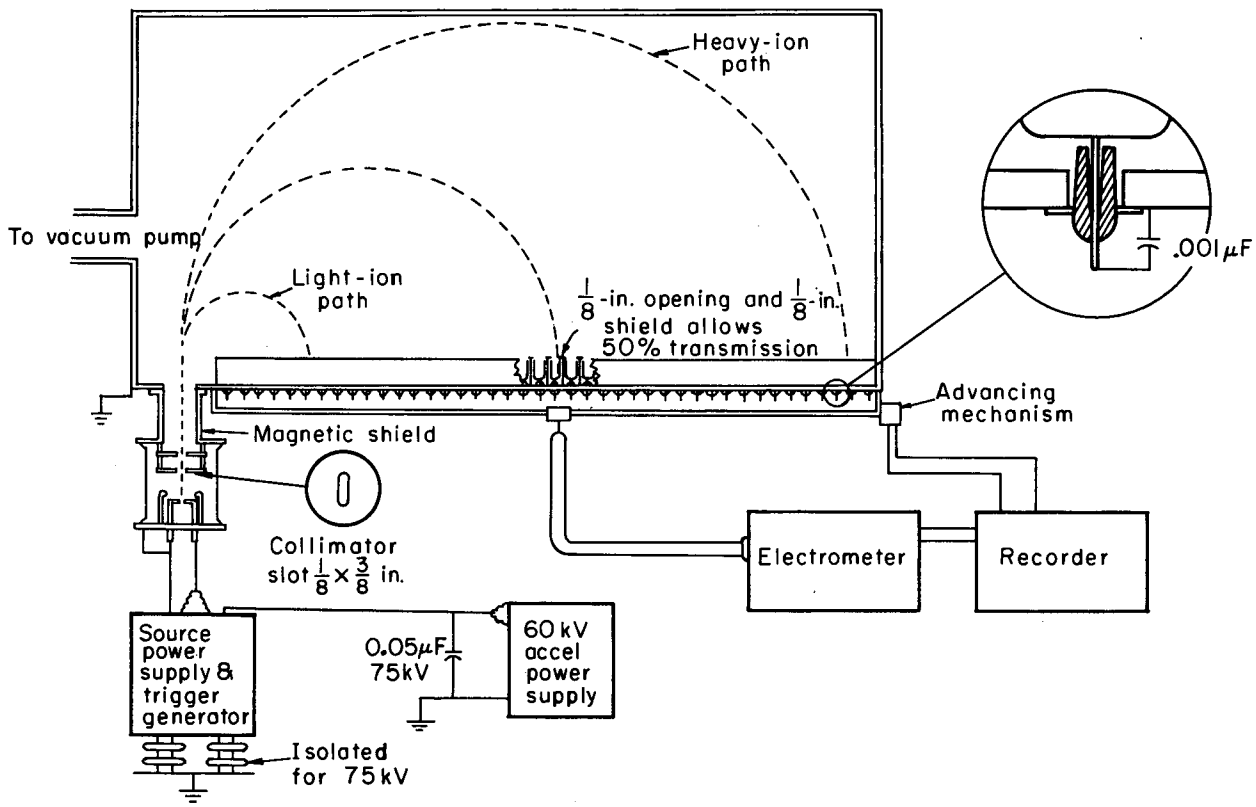

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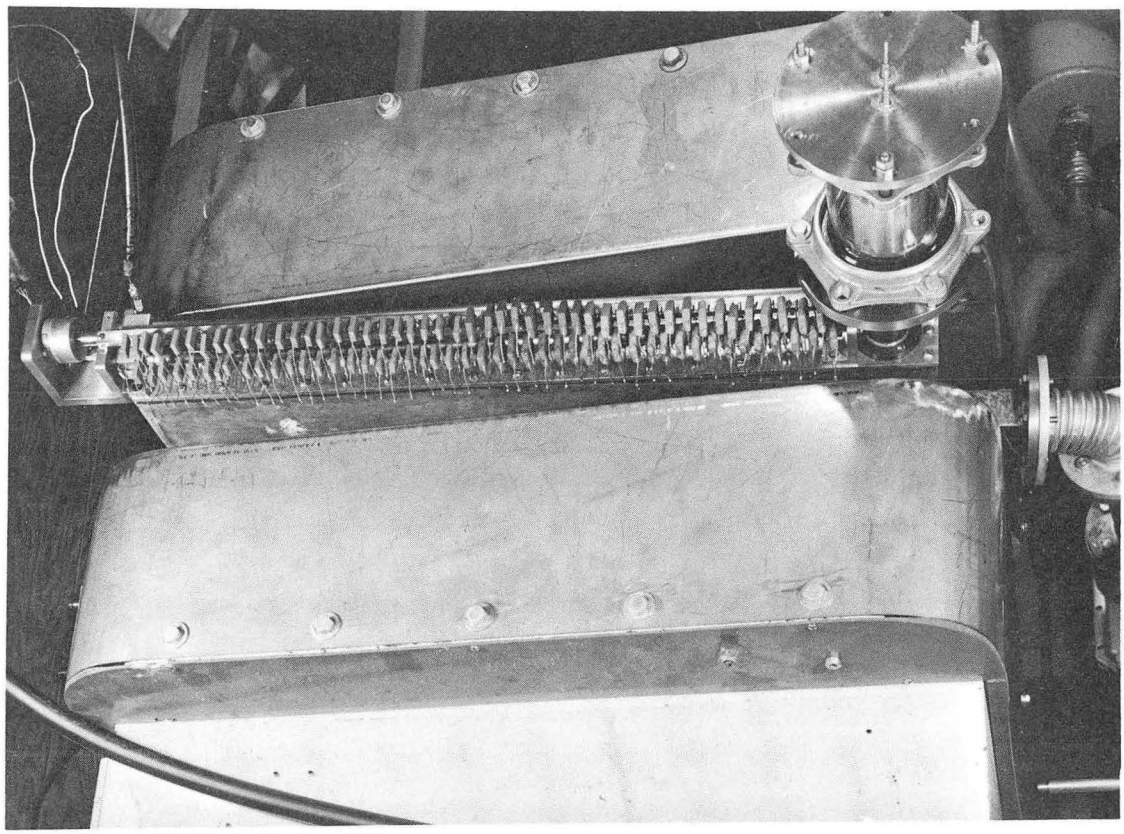
Fig. 1

ZN-4972

Fig. 2



ZN-4973

Fig. 3

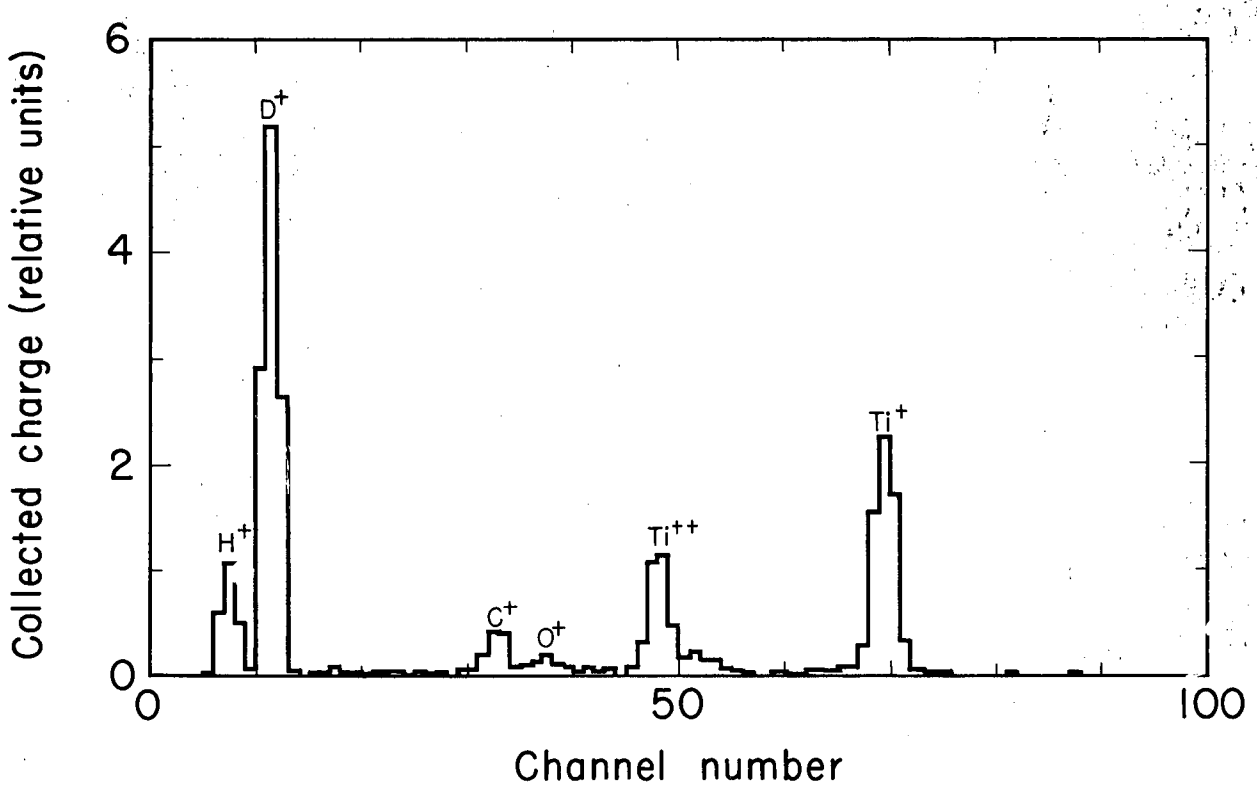


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Fig. 4