M.A. Gruntman, Identification of ions by their masses in multichannel energy analyzers, *Instruments and Experimental Techniques*, v.26, n.4, pt.2, p.943-945, 1983.

ISSN 0020-4412

Vol. 26, No. 4, Part 2, July-August, 1983

February, 1984

INETAK 26(4) 873–1000 (1983)

INSTRUMENTS AND EXPERIMENTAL TECHNIQUES

ПРИБОРЫ и ТЕХНИКА ЭКСПЕРИМЕНТА
(PRIBORY I TEKHNIKA EKSPERIMENTA)

TRANSLATED FROM RUSSIAN

CONSULTANTS BUREAU, NEW YORK

where U_{reg} is the regulated voltage of the avalanche diode D_{1s} and R_{fb} = 10 kΩ is the internal resistance of the DAC feedback. In the manual scanning mode any part of a mass spectrum can be scanned. For this purpose, it is necessary rapidly to acquire the code of the mass that corresponds to the beginning of the scanned part of the mass spectrum, and then to set the necessary scanning rate by resistor R_1. At the end of the scanned part of the spectrum the scanning is stopped by closing tumbler Sw_2 and the voltage of the scanning generator is reset to zero by pressing pushbutton Sw_3. The other tumblers are in the same positions as in the linear scanning mode.

Principal characteristics: scanning period of each of 16 chosen masses $T_6 = 16t_s$, where $t_s = 2.2R_2C_2$ = 0.1-50 msec is the scanning time for one mass; linear scanning duration $T_{1s} = 2.2R_1C_1 2^{n+k}$ = 6-600 sec, where k = 14 is the scaling factor, n = 10 is the capacity of the DAC used; range of output voltage of generator 0.01-4 V; instability of output voltage ≤0.05% for temperature variation from 10 to 30°C. The generator allows external digital controllers to be connected directly to the input of the internal memory without any alterations to the circuit. For this purpose pushbutton Sw_3 must be depressed to set a logical "1" level at the output of the internal memory.

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IDENTIFICATION OF IONS BY THEIR MASSES IN MULTICHANNEL ENERGY ANALYZERS

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UDC 539.074.6+533.9.082

A method is described for identifying ions by their masses with a time-of-flight technique which allows reliable separation of ions with masses of 1, 2, and 4 amu and an energy ≥3 keV. The particle detection efficiency is ≥20%. The necessary modification of the energy analyzer is described. The technique can be used for corpuscular diagnostics of high-temperature plasma.

Passive corpuscular diagnostics is one of the most important methods of investigating and monitoring the characteristics of high-temperature plasma in a system with magnetic confinement, e.g., in tokamaks [1, 2]. Neutral atoms which a plasma emits with an energy exceeding hundreds of electron-volts are usually analyzed with multichannel energy analyzers (MCA) [1]. In these analyzers the atoms are ionized in one way or another, deflected by an electrostatic field, are separated according to their energies, and are detected by several (up to 30) secondary-emission multipliers, each multiplier detecting only ions with a particular energy. Such an MCA is not capable of distinguishing the detected particles by their masses, and precisely this is extremely important to do, especially in the range from 1 to 4 amu, i.e., from H to He. The use of positive deflection of ions with a magnetic field for mass analysis of particles significantly complicates the technique [3]. As shown in this paper, the MCA need to be modified only slightly in order to carry out such analysis by the time-of-flight technique.

To identify ions by their masses, we used a detector—energy analyzer (DEA) of H atoms (Fig. 1), analogous to that described in [4-6]. A carbon force F with a thickness of 80 Å is placed at the inlet to the stainless steel casing of the DEA. At a distance of 2.5 cm behind this foil is a block B of two microchannel plates (MCP) set up in series in a chevron con-

Institute of Space Research, Academy of Sciences of the USSR, Moscow. Translated from Pribory i Tekhnika Éksperimenta, No. 4, pp. 182-184, July-August, 1983. Original article submitted August 4, 1982.

0020-4412/83/2604-0943$07.50

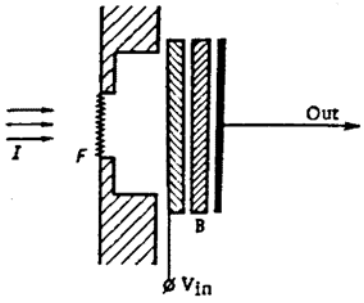

Fig. 1

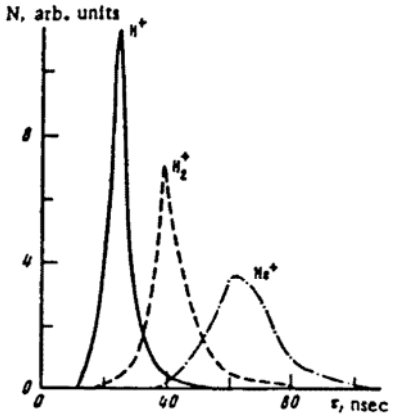

Fig. 2

Fig. 1. Schematic of detector—energy analyzer. F is a carbon foil 80 Å thick; I are H^+, H_2^+, and He^+ ions, and B is a block of microchannel plates.

Fig. 2. Time-of-flight spectra obtained during detection of 3-keV H^+, H_2^+, and He^+ ions.

figuration. The potential at the input of the MCP block is V_{in} = 100 V. The collector is at a high voltage (about 2 kV). A particle that traverses the foil and enters the DEA can cause emission of electrons from the back side of the foil — streaming emission; the electrons so produced are accelerated by the potential V_{in}, pass the particle itself, and are detected by the MCP block before the particle. The particle which had produced the electrons then arrives in the MCP block and is detected. The interval of time between these two successive pulses is determined by the times of flight of the particle and the electrons from the foil to the MCP block. From this we can determine the velocity (the energy, if the mass is known) of the particle detected. The case considered corresponds to the one-channel mode of time-of-flight analysis. The broadening of the time-of-flight spectrum during the detection of a monoenergetic beam is determined by the spread of the times of flight of the electrons and the particle from the foil to the detector as well as by the jitter of the MCP block and its electronic circuitry. When the DEA was used to detect hydrogen atoms with an energy of 600-3000 eV, its resolution — defined as $E_1/(E_1 - E_2)$, where E_1 and E_2 are the energies of monoenergetic beams, recording of which gives well-distinguished time-of-flight spectra — was 2 [5].

The DEA was used to detect H^+, H_2^+, and He^+ ion beams with an energy of 3000 eV. The diameter of the beams was 8 mm. The distance from the foil to the collector of the MCP block was 3 cm. The time-of-flight technique in the one-channel mode was described in detail in [5]. Since for a number of reasons it was difficult to obtain deuterium ions in the equipment employed, we used H_2^+ ions to imitate the detection of D^+ because the masses of H_2^+ and D^+ are practically the same. The energy losses of 3-keV D^+ ions in the 80-Å foil are not very large. Upon entering the foil the H_2^+ molecule breaks apart and its fragments move independently. They also lose a small fraction of their energy in the foil. The velocity after the foil, therefore, should not differ substantially from the velocities of the fragments of the H_2^+ molecule and the time-of-flight spectrum obtained by detecting D^+ should not differ significantly from that obtained with H_2^+.

The time-of-flight spectra obtained are presented in Fig. 2. The curves have been normalized by the total number of pulses acquired; τ is the difference between the times of flight of the particles and the electrons in the DEA. It is seen from Fig. 2 that H^+ and He^+ ions can be reliably separated from H_2^+. The detection efficiency for particles is fairly high: For 3-keV hydrogen atoms, for example, it is ~20%. An important characteristic of the DEA is its ability to isolate the useful signal that corresponds to the detection of particles from the background produced by radiation entering the detector [5, 6]. This makes it possible for the background count from the plasma radiation to be suppressed in the multichannel analyzer.

Let us discuss the prospects of the technique described here. If the multipliers, that detect ions with a particular energy, are replaced in multichannel analyzers by the DEA described above, will make it possible for neutral particles emitted by a plasma to be identified from their masses at the same time as an energy analysis is carried out.

Using the electronically most advantageous connection diagram for the MCP block (one in which the collector is at the potential of the ground while the detector input and, hence, the foil are at a potential of about −2 kV), we can accelerate the ions to be detected, this being important for the detection of ions with an energy less than 1 keV.

Several DEA in one multichannel analyzer can be replaced by one DEA which uses, e.g., a rectangular MCP, forming a strip that detects particles, and a collector which is divided into elements that correspond to different particle energies.

Some other possible applications of the DEA and its modifications for corpuscular diagnostics of high-temperature plasma are discussed in [5, 6].

In conclusion, the author expresses his wholehearted thanks to V. B. Leonas for useful discussions and Yu. V. Gott for kindly supplying specimens of thin foils.

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DETERMINATION OF THE THRESHOLD SENSITIVITY OF INFRARED-RADIATION DETECTORS

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UDC 621.384.326.2+53.082.52:53.082.56:53.082.6

A method is described for determining the threshold sensitivity and the time constant of two-dimensional infrared-radiation detectors made from cholesteric liquid crystals. The method is based on simulation of a heat pulse in the specimen under study when a calibrated current is passed through its substrate.

Three-dimensional infrared detectors based on cholesteric liquid crystals (CLC) are used extensively for the visual representation of the radiation of infrared lasers [1-3] and for measurement of the irradiance distribution they produce. Calibration of these detectors, however, is a fairly laborious operation that requires complicated apparatus [4]. We have developed a simple method of determining the threshold sensitivity and some time responses of detectors based on cholesteric-liquid crystal films. In this method, an electric current that forms a homogeneous thermal field is passed through a current-carrying graphite substrate that is in thermal contact with a pseudoencapsulated cholesteric-liquid crystal film. For this purpose, a thin Mylar film with a black grphite coating is stretched in a mounting-holder

All-Union Scientific-Research Institute of Opticophysical Measurements, Moscow. Translated from Pribory i Tekhnika Éksperimenta, No. 4, pp. 184-185, July-August, 1983. Original article submitted July 26, 1982.

0020-4412/83/2604-0945$07.50