Title
INSTRUMENTATION FOR THE IDENTIFICATION OF ELEMENT 102

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Publication Date
1959-04-01

UCRL 8722

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

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UCRL-8722

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Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

INSTRUMENTATION FOR THE IDENTIFICATION OF ELEMENT 102

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April 1959

Printed for the U. S. Atomic Energy Commission

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ABSTRACT

Two systems for the identification of the isotopes of transuranium elements are described. The first system incorporates a multiplex concept in which one multi-channel pulse-height analyzer processes data from a number of detectors. The second system utilizes a number of pulse-height and time sorting analyzers to record information derived from a single detector.

*This work was performed under the auspices of the U. S. Atomic Energy Commission.

INSTRUMENTATION FOR THE IDENTIFICATION OF ELEMENT 102

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April 1959

The first system of instrumentation was used to determine the half-life of an element 102 isotope by a somewhat indirect method.

A curium target was bombarded by a C^{12} beam of the Berkeley Heavy Ion Linear Accelerator. Sufficient momentum was transferred to the resulting 102 atoms to carry them out of the target through a very thin metallic coating into a region filled with helium. The initial charge on the recoil atoms is probably multiple but after being slowed by the gas they must only be singly positively charged. Under the proper physical and electric conditions these ions can be collected with high efficiency.

In these first experiments the 102 ions were collected on a metal belt maintained at a potential negative with respect to the target. Continuous motion of this belt transported the 102 atoms under a fixed collecting electrode with a potential more negative then the belt.

Approximately half of the Fm^{250} daughter atoms of the 102 alpha decay recoiled into the helium above the belt and were collected on the fixed electrode, (Figure 1).

The distribution of the daughter atoms on the collector, in the direction of tape motion, together with the tape speed, provided the information necessary to determine the alpha half-life of the parent 102 isotope.

After collecting daughter atoms for a period equal to several of their half-lives, the collecting electrode was removed from the target apparatus and divided into five equal length segments corresponding to consecutive equal time intervals.

Each of the segments was then placed in a separate Frisch grid ionization chamber.[1] The output pulses from these alpha detectors were then simultaneously pulse height analyzed in a single Los Alamos 100 channel kicksorter.[2]

In order to accomplish this analysis a multiplex system was assembled. This consisted of five parallel channels, each composed of preamplifier, pulse shaper, discriminator, and amplifier. Each channel was adjusted to provide output pulses with uniform energy-pulse-height relationships in the energy range of interest. These pulses were combined in a mixing and coding chassis and then fed to a discriminator amplifier unit to provide control of the combined detector signals.[3]

The combined spectrum was analyzed in the Los Alamos kicksorter which used twenty relays to drive a 10 x 10 matrix of registers. An additional twenty slave relays were added to the analyzer in order to store the analyzed pulses in two columns of a 10 column parallel entry Clary printer. Five columns of this printer were used to present internally generated timing information. The previously mentioned mixing and coding chassis contained a discriminator, trigger pair, and relay in each channel to supply detector identification signals to one of the remaining columns of the printer. Print-command signals were generated whenever any channel produced an identification signal.

Operation of an upperbound relay in the analyzer was used to identify an off-scale high energy pulse as a probable fission pulse.

In order to provide calibration information an automatic mercury pulser was developed. It sequentially programmed simulated alpha pulses to the separate detectors in steps equivalent to 10 kev over an adjustable 4 Mev energy range. This pulser also provided the printer with a signal identifying the resulting printed data as synthetic. Calibration information was normally obtained before and after data collection. In some cases a fixed energy pulse was supplied to the detectors at a relatively low repetition rate during data collection, (Figure 2).

An input gating relay muted the analyzer and the printer print-command during analysis of a pulse. In the event that more than one pulse arrived before closure of the input gate, the highest energy pulse was analyzed; however, the detector identification was ambiguous. Because of the low count rate involved this defect in the system was ignored. For the same reason the stacking of pulses within the 10 μsec shaping time was of even less significance.

The reduction of data from the printer tape was accomplished by hand.

On several occasions the collecting electrode was processed in an ion-exchange column before pulse-height analysis to insure that the observed alpha energy was due to the chemically identified Fm^{250} daughter of element 102^{254}.

No unusual or unique circuitry was used, and the system as originally assembled operated as expected for approximately one year without modification.

The second system to be described has been undergoing continuous change over a period of many months. In expanding the instrumentation to provide as much information as possible, many unexpected problems were encountered. Many of these have been solved in an empirical fashion which led to the present design.

In this system the production of the 102 ions and their collection on an aluminized mylar tape was accomplished in a manner simular to that of the previous system. However, the tape was not moved continuously byt periodically pulsed so that the area on which the 102 ions were collecting was rapidly moved into counting position in a Frisch grid ionization chamber.[1] In this case the counting time in the chamber was necessarily equal to the time during which the ions were collected.

Several methods of tape pull were tired. The one presently employed utilizes a solenoid operated valve to evacuate a shaped tape channel. This insured rapid but uniform tape travel with minimum inertia, (Fig. 3).

It was necessary to collect the 102 ions in helium while the grid chamber was operated with an argon-methane mixture. Because the mylar tape was common to both regions they were operated at atmospheric pressure with the grid chamber located beneath the collecting area. The difference in density of the gases was utilized to maintain their separation. Sufficient flow of the argon-methane mixture was provided to offset contamination through diffusion. It was empirically determined that the 102-ion collection efficiency was a function of the helium purity. Since the breakdown voltage of the gas was known to increase with air contamination, it was possible to construct a simple helium purity monitor.

A peak-reading voltmeter measured the breakdown voltage of a spark gap to which a sinusoidal voltage was applied through a current-limiting

resistor. The voltmeter output provided a means of adjusting the helium flow to maintain maximum collection efficiency.

Output pulses from the grid chamber were pre-amplified, shaped and fed to three pulse-height analyzers through appropriate amplifiers and discriminators. The first analyzer, a Los Alamos 100-channel kicksorter, used low amplification and a discriminator to reject alpha pulses and present a spontaneous fission spectrum. The second analyzer, a Penco Pa-4, was used to record a wide energy range alpha spectrum. The third analyzer, a modified Los Alamos kicksorter, analyzed a narrow range of energy in which the 102 alpha decay particles were observed. In conjunction with this analyzer, five 10-channel time analyzers were utilized to analyze the arrival time of pulses in five separate energy ranges of the narrow range pulse height analyzer, (Fig. 4).

A variable frequency oscillator driving a special scaler unit with appropriate delays and relays provided timing for tape transport, programming of the 10-channel time analyzers and muting of the amplifiers during the tape transport interval. Muting of these amplifiers and the preamplifier was also necessary during the HILAC beam bursts, which saturated the grid chamber with beam-induced gamma and beta activity. Control of the muting relay time duration was accomplished with standard Berkeley scaler-gating chasses, (Fig. 4).

The input to the wide range alpha analyzer was also presented to a noise monitoring and alpha count rate chassis . A discriminator in this chassis was set above electronic and beta activity background noise and all pulses below this level were integrated. A second discriminator was set below minimum alpha pulse-height and integrated all pulses above it.

Strip chart recorders were used to provide a continuous indication of these functions as well as accelerator beam current before and after passing through the target and collection region. Target voltage and current were also monitored on a strip chart recorded.

Monitoring of the mechanical operation of the target apparatus was accomplished through the use of a remote control closed circuit television system.

Results

The use of the first system provided a determination of the 3-second half-life of an isotope of element 102, identified from nuclear systematics as 102^{254} produced in the reaction ($C^{12} + Cm^{246} \longrightarrow 102^{254} + 4n$). The system was previously used in bombardments of Pu^{240} with C^{12} ions to identify a new isotope of element 100, Fm^{248}.[4]

The second system, in addition to providing additional data to substantiate the 102^{254} half-life determination, indicated an alpha energy of 8.3 Mev and a surprisingly high spontaneous fission branching ratio of 1/3. In addition, a second isotope of 102 with a half-life of 10 to 15 seconds and an energy of 8.8 Mev was tentatively identified as 102^{253} from the reaction (C^{12} 2 $Cm^{246} \longrightarrow 102^{253} + 5n$). Recent bombardments with C^{13} have yielded somewhat larger amounts of this activity, most probably from the reaction ($C^{13} + Cm^{244} \longrightarrow 102^{253} + 4n$).[5]

Conclusions

The multiplex system described demonstrates the feasibility of using a single analyzer to handle information originating in a number of detectors. Design and development of multiplex systems utilizing faster analyzers and data storage on punched and magnetic tape to facilitate data reductions is proceeding at Berkeley.

The second system has provided a useful means of identifying 102 isotopes and with further refinements may identify additional new elements.

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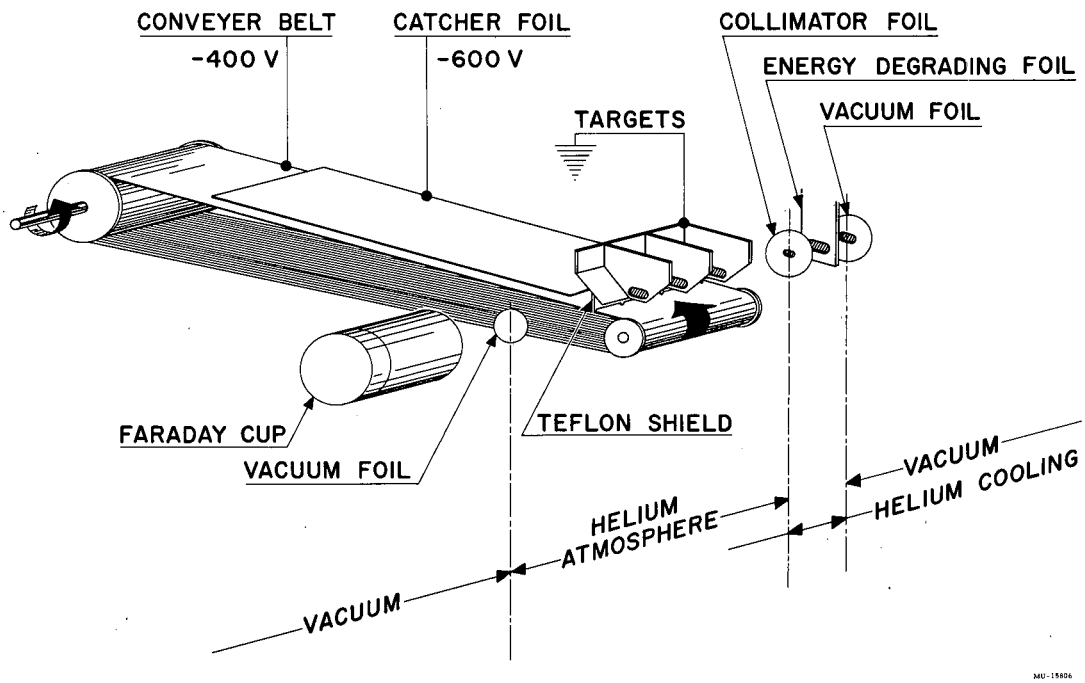

Fig. 1. Schematic diagram of multiplex system target apparatus.

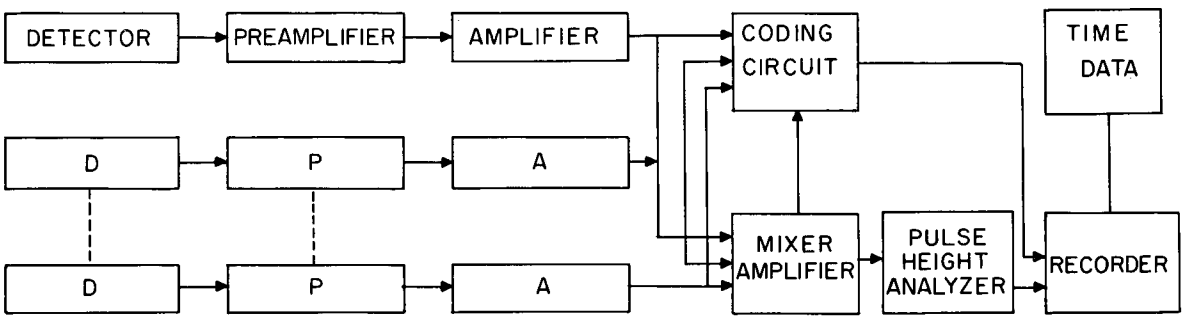

Fig. 2. Block diagram of multiplex electronic equipment.

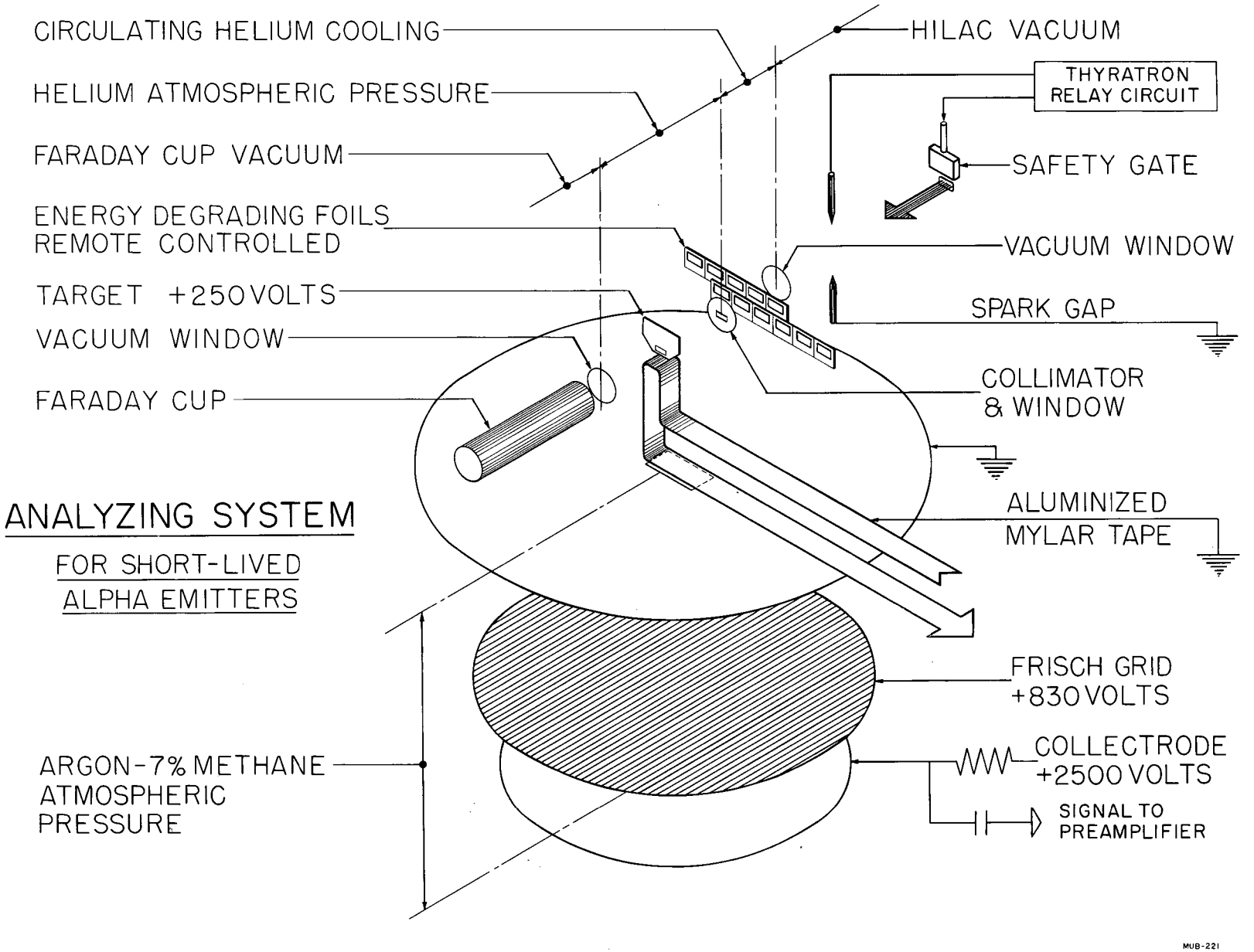

Fig. 3. Schematic diagram of target apparatus for multiplex analyzer system.

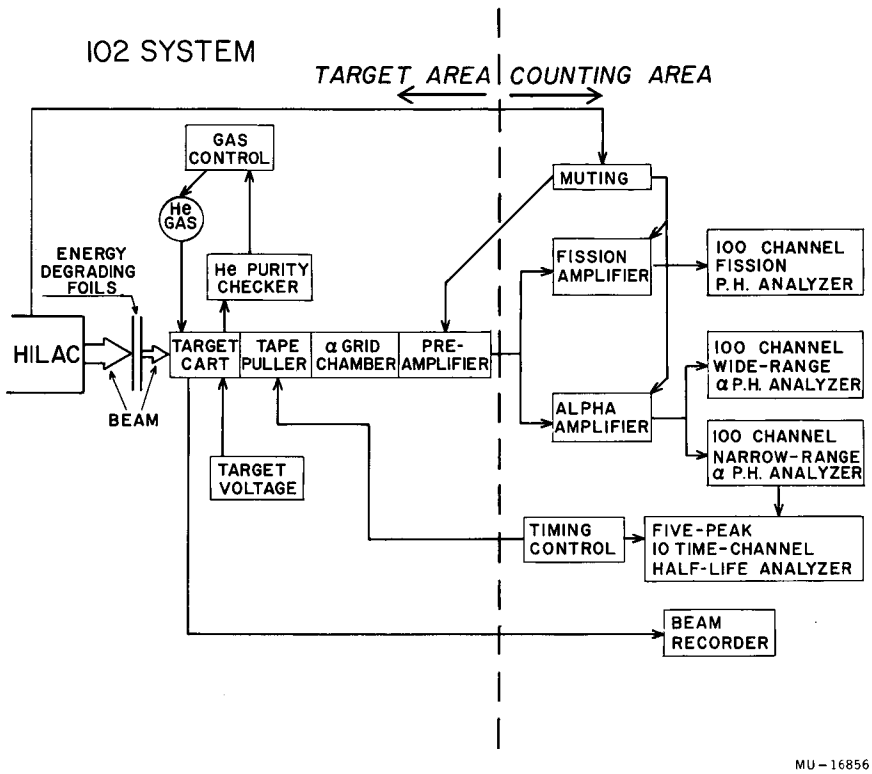

Fig. 4. Block diagram of multiple analyzer system.