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A COMPACT TAPE TRANSPORT STATIONFOR ON-LINE STUDIES OF SHORT-LIVED NUCLIDES

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ABSTRACT

A compact tape transport system which is used for collection of short-lived nuclides from an on-line isotope separator has been developed. The tape drive system is based on a stepping motor which is kept in air. A drive shaft with a vacuum feed-through connects the motor to the tape deck. The tape deck can easily be modified to incorporate several different detector set-ups. One of these, which uses a position sensitive detector for half-life determinations of short-lived charged particle emitting nuclides is described in detail.

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1. Introduction

The use of on-line mass separators has made a large number of new, short-lived radioactive nuclides available for studies¹⁾. One of the problems in studying such nuclides at an in-beam measuring station is the background radiation built up from daughter products and long-lived contaminants. In order to minimize this radiation the activity to be studied has to be collected and transported to a remote measuring station and after the measurement the sample has to be removed from this station. Disc collector systems²⁾ and tape transport systems³⁻⁷⁾ has been found to be very useful for this purpose.

In the present paper we describe a tape transport system which has the advantage of being compact and easy to modify. Although this tape unit has been used in many different applications we will in this paper make special emphasis on its use for half-life measurements of charged particle emitting activities.

2. Mechanical construction

Apart from the control electronics the tape system consists of three main parts (fig. 1):

- 1 The tape drive motor placed outside vacuum
- 2 The drive shaft and the associated vacuum feed-through
- 3 The tape deck placed inside a vacuum tank

The drive motor normally used is a commercially available EME (Zürich) stepping motor which makes 200 steps/turn. A drive pulse initiates each step which corresponds to a tape displacement of 0.25 mm. The extent of the tape movement, the distance

between the collect position and one of the many available measuring stations, is regulated by a digital pulse train from the control electronics. The drive motor accepts a pulse rate of up to 500 Hz corresponding to a tape speed of 12.5 cm/s. In order to obtain a faster/more precise tape movement the motor can quickly be changed to similar motors with less/more steps per turn.

The drive shaft is the only non-exchangable part of the system. The upper end of the shaft is connected to the drive motor and the axis passes via a vacuum feed-through into the vacuum tank. The axis ends with a capstan which is in contact with the drive wheel of the tape cassette.

The tape we have chosen for the present tape station is a commercially available 3M company cassette tape. The DC 300 A cassette contains 90 m of 7 mm wide tape but its dimensions is only 10 x 15 x 1.7 cm. The advantage of this cassette, apart from its small size and rapid exchange, is the drive system which consists of a teflon string mounted on three wheels, of which one is pressed against the drive shaft capstan (fig. 1 and 2). This string is also in contact with the two tape reels, thus ensuring that the peripheral velocities of both reels are the same. Despite the smallness of all mechanical parts of this system the tape mechanism can withstand accelerations of up to 50 m/s^2 .

3. Standard operation

During standard operation the tape is moved after each collection from the collection point to the measuring station in use. A collection starts when a large bias on a pair of

electrostatic deflector plates, upstreams of the tape system is switched off, and the beam is directed onto the tape through a 3 x 5 mm collimator. After a preset collection time simultaneous pulses from the control electronics interrupt the beam and move the sample on the tape to a particle detector. The typical distance between the collection spot and the solid state detector is 5 cm, meaning a transport time of about 0.4 sec. with the normal drive motor mounted. A cycle rate of 2 Hz can thus be obtained and around 1800 samples can be taken before a tape rewind is necessary. A scaler records all drive pulses given to the motor and interrupts operation when a preset value has been reached, indicating that the tape is running out.

This mode of operation has been used to measure energy spectra of charged particles from delayed particle emitters or ground state alpha emitters under favourable background conditions. The standard mode of operation has also been used to measure half-lives of nuclides that are produced in so large amounts that the charged particle count rate is higher than one per second. However, when either the production yield or the particle branch is very low too much data is lost because of the discontinuous collection used in this technique and for such cases the tape system is operated in a continuous collection mode described below.

4. Continuous operation

This mode of operation has been used to determine half-lives of nuclides produced in extremely small amounts, with charged particle count rates of down to 0.007 per second. The ion beam is here continuously collected on the tape which moves with a constant, preselected speed. After the collection point the tape passes along the surface of a 45 mm long position sensitive detector.

This detector is placed along the direction of the ion beam and the tape is bent in 90° angle just at the front end of the sensitive area of the detector (see inset fig. 1). The collection point is in this way kept close to the detector (6 mm) which permits the determination of very short half-lives. The energy resolution of the detector is 42 keV FWHM and the position resolution is 0.5 mm FWHM.

The halflife measurements with this system were performed in the following way. The time range to be covered, i.e. the time taken for the tape to traverse the sensitive area of the detector, was selected by the rate of motor drive pulses. The energy and position signals from the detector were treated as two-dimensional coincidences and stored event by event on magnetic tape. In a subsequent sorting a position spectrum was built up from those position signals which correspond to energy signals inside a selected gate. This position spectrum was then converted to a time spectrum using the known speed of the tape.

The system described here has a high counting efficiency since it uses a continuous collection. The total efficiency of our system, i.e. the number of atoms whose decay has been recorded compared to the number of atoms produced, is around 25%. The necessary corrections for the variation of the solid angle of the position sensitive detector as a function of the source position along the tape, can easily be calculated and one finds that the solid angle is practically constant over the greatest part of the detector.

As a test of the system, the half-lives of several known nuclides were remeasured with this technique and as an example the result for ^{179}Hg is shown in fig. 3.

A few examples of the experimental conditions prevalent when this detector set-up was used and the results of half-life measurements on some new nuclides are given in table 1. The shortest half-life measured with this tape unit is 48 ms which is the result obtained for the lightest known isotope of francium⁹⁾.

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Table 1.

Nuclide	Production rate atom/s	Particle radiation	Particle branch	$T_{1/2}$
^{99}Cd	450	delayed protons	$1.7 \cdot 10^{-3}$	16 ± 3 s
^{114}Cs	2	" "	$3 \cdot 10^{-2}$ xx	0.7 ± 0.2 s
^{153}Yb	60	alphas ^x	0.9 ^x	4.0 ± 0.5 s
^{177}Hg	$2.5 \cdot 10^{-2}$	"	1 xx	170 ± 50 ms
^{201}Fr	0.5	"	1 xx	48 ± 15 ms

^x ^{153}Yb is not an alpha emitter. Half-life obtained from the decay curve of the alpha emitting daughter ^{153}Tm .

xx Estimated branch

Figure captions

1. General view of the tape station. The drive motor (1) is placed in air and a drive shaft (2) connects the motor with the tape deck (3). The movement of the drive shaft capstan is transferred to the two tape reels via a teflon string (4) mounted on three small wheels. The ion beam, seen as a black arrow, is directed through a collimator (5) and is collected on the tape (6) which subsequently passes in front of a position sensitive detector (7). An enlarged vertical view of the area around the collection spot is shown in the inset.
2. Photograph of the 3M DC 300 A tape cassette. When mounted on the tape deck (Fig. 1) the collection spot is situated at about the right edge of the photograph and the measuring stations are further away to the right.
3. Decay data for ^{179}Hg obtained with the position sensitive detector. The halflife measured with this system is compared (upper right corner) with the result from a previous measurement using the multispectrum analysis technique⁸⁾.

Fig. 1

Fig. 2

Fig. 3