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II–8 Implantation Techniques for Measuring Magnetic Moments of Isomeric Nuclear States*

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The techniques used for measuring magnetic moments of long living ($\tau \gtrsim 50$ ms) isomeric states[1–3) have relied on obtaining polarized nuclei and observing the β-ray anisotropy. With (0^{16}, xnp) and (α, xn) reactions it is possible to populate many interesting isomers in a large number of nuclei. However if no coincident particles are observed or if the experimental setup is symmetric around the beam axis the excited states are only aligned and polarization sensitive methods cannot be applied. An apparatus for a technique that used the anisotropy of the emitted γ-rays to detect the nuclear alignment is shown in Fig. 1.

The beam strikes the thin target which is placed between the pole pieces of a magnet providing a longitudinal holding field. The reaction products are emitted in a forward cone and travel in vacuum to a catcher which is not hit by the direct beam. The transferred alignment can be selectively destroyed in the catcher by a radio-frequency field. We have concentrated on the reactions $Si^{28}(0^{16}$, p, n)Sc^{42} (7^+, 61 sec) and $Ca^{40}(0^{16}$, 2p, n)Fe^{53}($19/2^-$, 150 sec). The γ-rays used to detect a nuclear alignment are the $6^+ - 4^+$ transition in Ca^{42} following β-decay of $Sc^{42}(7^+)$ and the $19/2^- - 11/2^-$ transition in Fe^{53}. In order to verify the large initial alignment of these high spin states by the heavy ion reaction we measured the γ-ray angular distribution for a similar reaction, $Ca^{40}(0^{16}$, 3p)Mn^{53}(15/2, 12 psec), leading to a short lived and therefore almost unperturbed state. For an incident energy of 40 MeV the measured ratio $I(0°)/I(90°)$ for the $15/2 - 11/2$ transition was 1.4 ± 0.1.

Assuming the reactions of interest have similar alignment, the next step is to show that the nuclei can be transferred from the target to the stopper in the longitudinal holding field without significant loss of alignment. This was done by performing a decoupling experiment on Fe^{57} recoiling in vacuum. A 1.9 mg/cm² Fe^{57} target was Coulomb-excited by a 30 MeV oxygen beam. The recoiling Fe^{57} ions were collimated into a forward cone of half opening angle 20° and implanted into a copper catcher. The lead collimator shielded the γ-counter from the γ-rays emitted by the large angle recoils and provided for a high observed nuclear alignment. Due to their different multipolarities (M1/E2 and E2) the 122 keV and 136 keV γ-rays have anisotropies of opposite sign and the ratio of their intensities observed in a Ge(Li) counter at 90° is a sensitive measure of the dealignment in vacuum. Figure 2 shows this ratio as a function of the longitudinal magnetic field for the Coulomb excited Fe^{57} and for a Co^{57} source (no alignment). The maximum expected ratio assuming full decoupling and including solid angle corrections is also shown. For the Sc^{42} reaction we expect the decoupling to occur at comparable fields.

The crucial part of the experiment is the choice of the catcher material to preserve the nuclear alignment for long times. Because our geometry does not easily

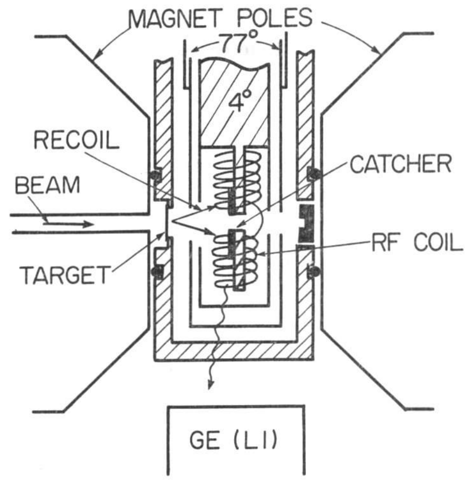

Fig. 1. Experimental setup, showing the arrangement of target, catcher and cryostat between the pole pieces of the electromagnet.

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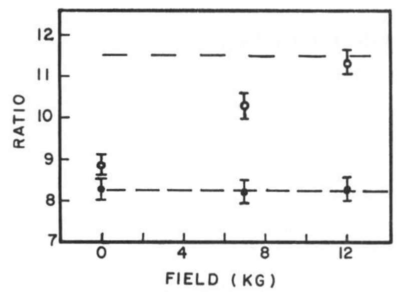

Fig. 2. Ratio of the 122 keV to 136 keV intensities for Coulomb excited Fe^{57} (open circles) and the Co^{57} source. The upper dotted line gives the expected maximum ratio for full decoupling.

allow observation at angles different from 90°, a special technique has been employed that tests whether the alignment has been preserved. A sample of aligned nuclei is implanted into the catcher by turning the beam on for about one minute with a 8 kG holding field on. A 100 G transverse field is also applied continously with a small permanent magnet. The beam is turned off and the decay of the excited nuclei is monitored with a Ge(Li) detector at 90° to the beam direction. At a later time the magnetic field is rotated by 90° by turning off the large field so that only the 100 G transverse field is effective. If the alignment is preserved, a sudden change in the counting rate proportional to $W(0°)/W(90°)$ will be observed after the time at which the field was rotated.

The experiments done so far include room temperature runs on $Sc^{42}(7^+)$ implanted into Si, KI, ScN and $Fe^{53}(19/2^-)$ into Si, Ge, KI and MgO, with the catcher separated from the target, and low temperature runs on $Sc^{42}(7^+)$ into hyperpure Si, with the silicon acting both as target and catcher. Within the statistical accuracy obtained so far no step was observed on the exponentially decaying counting rate $Ne^{-t/\tau}$ at the moment when the magnetic field was rotated. Assuming an initial γ-ray anisotropy $W(0°)/W(90°) = 1.3$ and full decoupling during the vacuum flight, the negative results obtained so far indicate that less than 25% of the nuclei have preserved their full alignment or else that the nuclear relaxation times for implantation into these catchers are shorter than the nuclear halflife. Low temperature experiments with target and stopper separated to avoid beam heating and additional relaxation by the radiation damage due to the direct beam in the catcher are in progress.

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