QUADRUPOLE FREQUENCY MEASUREMENTS IN CUBIC AND MAGNETIC HOST MATERIALS * **

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The Level Mixing Spectroscopy (LEMS) method has proven to be a powerful method to determine the quadrupole moment of high spin isomers. There are some limitations on the use of the method which are due to the fact that a non cubic host providing an electric field gradient and a large superconducting magnet are needed. In this contribution we report on the use of cubic host materials as a first expansion of the applicability of the LEMS method towards a wider region on the nuclear chart. In two experiments we have shown that a defect-associated electric field gradient, induced by the nuclear reaction in a cubic host material, is reproducible and can be used to determine quadrupole moments. We also discuss how the use of magnetic host materials cancels the need for a superconducting magnet by taking advantage of the very strong, temperature dependent hyperfine fields near the Curie temperature.

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1. Introduction

In a LEMS experiment the interaction of a nucleus with a combined electric and magnetic interaction is evaluated [1]. The electric interaction is provided by implanting the nucleus in an environment where it will be

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submitted to an electric field gradient. The most straightforward way is to implant the nucleus in a non cubic material.

From previous implantation studies, it is known that due to implantation a lot of defects can be created in the target lattices [2, 3]. These defects will introduce a defect associated electric field gradient (DAEF) at the site of the implanted nucleus. In our experiments we show that such a DAEF is reproducible, in other words that the creation of the defects is not depending on the initial beam type, nor the initial beam energy. We were able to prove beyond any doubt, that in this way the LEMS method is capable of measuring quadrupole frequencies in cubic host materials [4].

So far the magnetic interaction has been provided by a superconducting magnet. In the next step of this experimental program, we would like to prove the magnets redundancy by using magnetic materials, *e.g.* Ni. Since Ni is a ferromagnetic material, a hyperfine field will be present below its Curie Temperature (T_c(Ni) = 633K) and we can easily vary it as a function of the temperature. If we prove this possibility, a LEMS measurement will be easier to perform in a multidetector system and can then be used to gather nuclear structure information on sparsely populated nuclear states.

2. Principles of the LEMS method

The nuclei of interest are produced and oriented in a fusion evaporation reaction. Because of the large transfer of angular momentum from the projectile nucleus to the compound nucleus, the spin of the compound nucleus will be oriented perpendicular to the beamline. This way we obtain an aligned ensemble of nuclei [5].

Immediately after the nuclear reaction we may represent the spins of this oriented ensemble as if they form a wheel around the beam axis (Fig. 1b). The recoiling nuclei are caught in a host (*e.g.* the target itself) which provides an electric field gradient. If a single crystal host is oriented such that the symmetry axis of the EFG deviates with an angle β from the symmetry axis of the initial orientation, the quadrupole interaction will cause the wheel to flip (Fig. 1a). The orientation is strongly destroyed and the spins are more isotropically distributed. A similar thing happens in a polycrystal. On the other hand, if we apply a strong magnetic field B along the symmetry axis of the initial orientation, the quadrupole interaction can be neglected and the spins perform a Larmour precession around B. Since this is a precession around a symmetry axis of the oriented ensemble, no change of the orientation occurs (Fig. 1b) and we measure the anisotropy of the initial orientation. At intermediate magnetic fields, the slope of the curve will be sensitive to the ratio of the quadrupole and magnetic interaction frequency. A LEMS curve (Fig. 1c) is calculated numerically by diagonaliz-

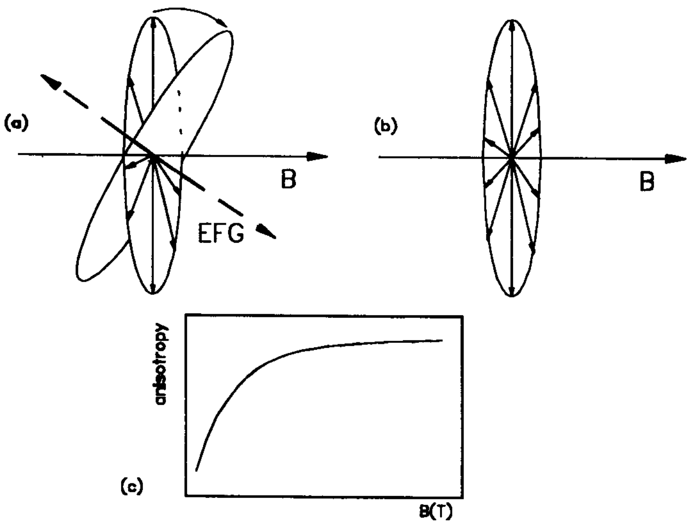

Fig. 1. Schematic representation of the changing orientation using the LEMS method.

ing the Level Mixing Hamiltonian and introducing the result in the angular distribution of the isomeric γ-decay.

3. The reproducibility of defect associated electric field gradients

Because of the incomplete charge symmetry in non-cubic host materials, an electric field gradient is always present. The most favored experimental approach is to work with a target material that also serves as a host, which forces us to use non-cubic target materials. To avoid this limitation we tested the use of cubic host materials and DAEFs. We chose to examine the LEMS curves for the $I^{\pi} = 8^{+}$ isomeric state in ^{204}Po of which all nuclear parameters are known. In a first experiment we used a ^{12}C beam at 70 MeV on a thick ^{nat}Pt target and in the second a ^{13}C beam at 78 MeV on the same target. The cubic Pt material also served as a host.

In both experiments we could resolve two interaction frequencies. The Po-nuclei were distributed among three sites : one substitutional (no EFG) and two defect associated sites [6]. The strengths of these field gradients were calculated and found to be reproducible. This can be explained by the fact that defects are created in the last moments of the thermal spike of the recoiling atom [7]. In the first moments of its path, it loses energy due to electronic collisions (inelastic collisions with conduction electrons). Only when the atom has cooled down to less than 5 keV, atomic interactions occur and lattice atoms are kicked out of place. This induces a cascade of collisions leaving the interacting atom on a substitutional site with a vacancy nearby and an interstitial far enough, not to influence the nucleus of interest. The largest DAEF ($10 \pm 2\ 10^{17}$ V/cm^2) is probably due to a vacancy trapped in a first neighbour position. Such strong electric field gradients enable us to measure the quadrupole moment of isomers with lifetimes down to 20–30 ns.

4. LEMS measurements using magnetic materials

The maximum field of our actual superconducting magnet ($B_{\max} = 4.4T$) is often not enough to perform LEMS measurements in an optimal way. Another problem is that because of the size and the construction of the magnet, the method can not be implemented in multi-detector systems and detectors can only be used at fixed positions with respect to the magnet.

To solve these problems, we try to use the temperature dependent hyperfine field in magnetic host materials. Saturated hyperfine fields can easily reach values to 100T at low temperature and their strength can be varied by increasing the temperature [8].

An oven with temperature controle is very small and has less construction materials. To orient the hyperfine field in a preferential direction, still a small external field needs to be applied. In an external magnetic field a tail appears in the curve of the hyperfine field around T_c [9]. This will help us to work with a feasible sensitivity of the temperature control. A careful study of all parameters for such an experiment is being made for ^{69}Ge isomers in Ni.

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