

LEMS QUADRUPOLE INTERACTION MEASUREMENTS ON HIGH SPIN ISOMERS
IN At AND Bi NUCLEI

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Our group has developed a very simple and easy method 'LEMS' (Level Mixing Spectroscopy) to determine quadrupole interactions of isomeric nuclear states. It is an extension of LMR (Level Mixing Resonance) ¹⁻³ to large misalignment angles and even to polycrystalline samples. In LEMS an isomeric state is produced and oriented by nuclear reaction. In the isomeric state the nucleus is submitted to an electric quadrupole interaction by recoil implantation into a hexagonal single crystal. An external magnetic field is applied in the beam direction and provides an interaction ω_H (fig. 1). As a function of the magnetic field strenght tree situations occur. If $\omega_H \ll \omega_Q$ the initial orientation is perturbed by the quadrupole interaction to a level depending on the angle β between c-axis and beam direction. For $\omega_H \gg \omega_Q$ the nuclear spin is completely decoupled from the quadrupole interaction and revolves around the magnetic field such that the initial alignment is preserved. In the intermediate case $\omega_H \approx \omega_Q$ the orientation is partially preserved and can be calculated numerically. Fig. 2 and 3 show LEMS curves as a function of the essential parameter $\omega_H/3I\omega_Q$, that can be determined from an experiment. Since the magnetic moment is usually very accurately known, the quadrupole interaction can be derived.

The features of LEMS as compared to existing methods, are summarized in table I. The lifetime limits depend on the system investigated and typical numbers are given.

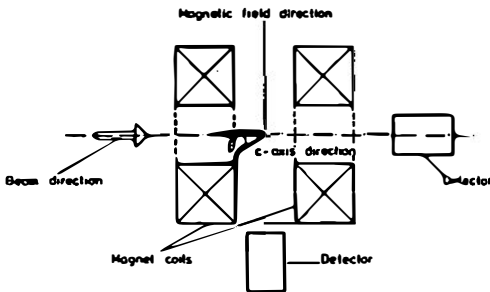


Fig.1. Experimental set-up

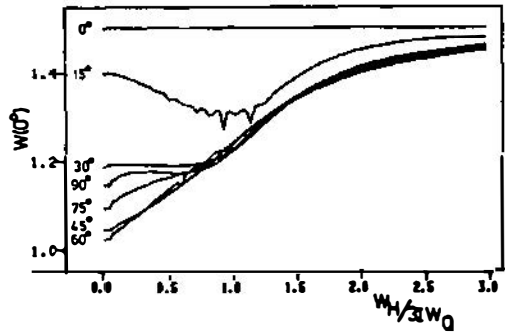


Fig.2. LEMS curves for different β

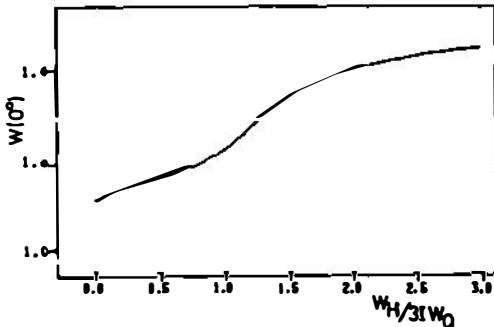


Fig.3. Polycrystal LEMS curve

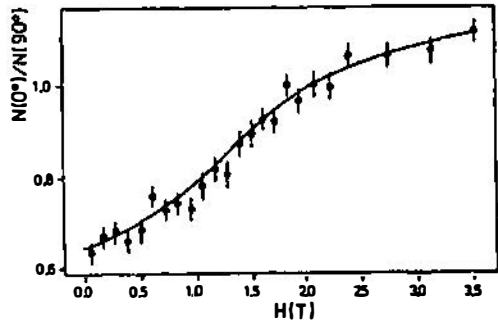


Fig.4. ²¹⁰At, 557 keV transition

Table I. Features of LEMS, LMR and TDPAD

Method	Lower lifetime	Upper lifetime	Accuracy	High spin	Radiation damage
LEMS	10ns	50ms	5-10%	no problems	inertive
LMR	100ns	50ms	1% ^c	very difficult	very sensitive
TDPAD	10ns	20μs	1%	difficult	sensitive

Another advantage of LEMS, not clear from table I, is its speed. Fig. 4 shows an experimental curve for the 19^+ state in ^{210}At that has been measured during a typical run of 10 hours beam time. Our results for several Bi and At isomers are listed in table II. For completeness, quadrupole interactions measured by TDPAD taken from ref. ⁴, are also included.

Table II. Experimental results

Probe	Spin	Half-life	Excitation energy (keV)	Host	eQV _{zz} (LEMS) (MHz)	eQV _{zz} (TDPAD) (MHz)
^{211}At	$29/2^+$	70ns	2641	Bi	150(20) ⁵	163(7)
	$39/2^-$	4.2μs	4816	Bi	305(25) ⁶	-
^{210}At	11^+	30ns	1363	Bi	-	104(6)
	15^-	0.8μs	2550	Bi	220(15) ⁷	196(2)
	19^+	4.0μs	4028	Bi	350(20) ⁸	-
^{209}At	$21/2^-$	25ns	1428	Bi	-	126(5)
	$29/2^+$	875ns	2429	Bi	240(20) ⁹	242(2)
^{208}At	16^-	1.5μs	2276	Bi	270(25) ^{**}	-
^{207}Bi	$21/2^+$	182μs	2102	Tl	0.405(20) ¹⁰	-
^{206}Bi	10^-	880μs	1045	Tl	0.445(30) ¹¹	-
					1.30(15) [*]	-
^{204}Bi	10^-	13ms	808	Tl	1.68(15) ^{*11}	-
^{202}Bi	10^-	3μs	598+x	Tl	1.10(10) ¹²	-

The magnetic moments needed to extract the quadrupole interaction from the LEMS results are taken from the references quoted next to the value. For the 16^- isomer in ^{208}At the magnetic moment is presently unknown and the result indicated with ** is derived with a probable g-factor of 1. LEMS measurements were performed at 450K except those labeled *, these were done at 4K because of thermal relaxation problem due to this long half-life. A large variation of the EFG in Tl between 4K and 480K is observed for the 10^- state of ^{206}Bi , this agrees with data for Tl¹³. The variation of quadrupole moments behaves as predicted by Anderson et al. ¹⁴ but detailed calculations still have to be performed. The ability of LEMS to measure where other methods fail is clearly demonstrated.

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